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INSTITUTE OF THE AERONAUTICAL SCIENCES

JUNE 1952

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Cover—This photograph, the first to have been released by the Air Force of Bell Aircraft Corporation's liquid rocket-motor activities, shows two rocket power plants during simultaneous firing at Bell's Wheatfield Plant Test Center. Bell, which designed these rockets for use in its guided missiles, has Air Force and Navy contracts for guided-missile air frames and rocket power plants in the air-to-ground and air-to-air missile categories.

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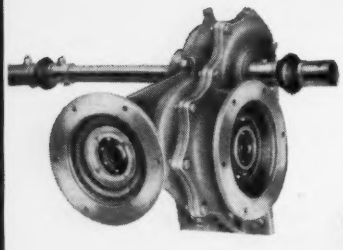

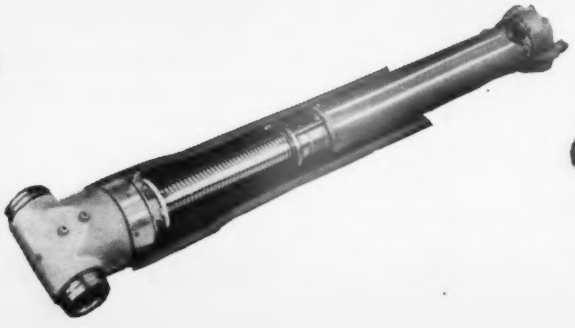

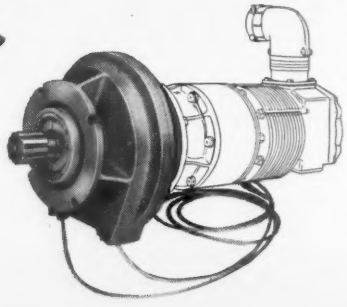

I. A. S. News

A Record of People and Events of Interest to Institute Members

Preliminary Announcement of the 1952 Annual Summer Meeting

Fourth in a Series of Annual Summer Programs To Be Held on July 16 to 18 in the I.A.S. Western Headquarters Building; The Honorable Dan A. Kimball Scheduled To Address Annual Summer Meeting Dinner

THE 1952 ANNUAL SUMMER MEETING of the Institute of the Aeronautical Sciences, to be held on July 16 to 18 at the I.A.S. Western Headquarters Building, 7660 Beverly Blvd., Los Angeles, will afford aeronautical engineers and scientists from the United States and other countries an opportunity to attend the delivery of important papers by many of the world's specialists in the aeronautical sciences.

The hosts for the forthcoming meeting will be, as in the past, the executive and general membership of the Los Angeles Section. Chairman of this section is Allen E. Puckett, Head, Missile Aerodynamics Section, Hughes Aircraft Company Division, Hughes Tool Company.

▸ **Dinner Speaker**—The Honorable Dan A. Kimball, Secretary of the Navy, is scheduled as the principal speaker for the 1952 Annual Summer Meeting Dinner, which will be held on the evening of July 16 in the Embassy Room of the Ambassador Hotel. A reception in Mr. Kimball's honor will take place immediately before the dinner and will begin at 6:30 p.m. Dinner will be served at 7:00 p.m.

▸ **Awards**—In accordance with custom, the dinner will be the occasion at which The Thurman H. Bane Award and The Octave Chanute Award are to be presented. These two annual awards will be given to their respective recipients by the Institute's President, Wellwood E. Beall, Senior Vice-President, Boeing Airplane Company. The recipients of these awards will be announced at a subsequent date.

▸ **Technical Sessions**—In all, there will be five technical sessions—four open and one closed—during the 3-day meeting. Registration for all five sessions will begin at 8:30 a.m. on Wednesday, July 16.

Two open technical sessions are scheduled for the first day. These will be on Aerodynamics and on Structures, the former convening on Wednesday morning at 9:00 a.m. and the latter assembling that afternoon at 1:30 p.m. The evening of this day will be occupied with the Annual Summer Meeting Dinner.

A trip aboard an aircraft carrier for approximately 200 members has been arranged for July 17. That evening a closed session on Design will be held. More complete information on the carrier trip and classified session should be in the hands of I.A.S. members by this time.

The final two sessions, both of them open, will meet on Friday, July 18. The 9:00 a.m. session will be on Propulsion; the 1:30 p.m. session will be on Design.

The tentative program for the 1952 Annual Summer Meeting will be found on page 18 of this issue.

The Honorable Dan A. Kimball
Secretary of the Navy

▸ **Program Committee**—Directly responsible for the planning of this forthcoming meeting is the Program Committee of the Los Angeles Section. This committee, under the direction of its Chairman, R. Richard Heppe, Aerodynamics Group Engineer, Lockheed Aircraft Corporation, has gone to infinite pains to ensure the success of this meeting. Therefore, to Mr. Heppe and to each member of his committee go the thanks and appreciation of every member of the Institute of the Aeronautical Sciences. There is little doubt but that all attending engineers and scientists will receive sufficient quantities of "food for thought" from the various discussions that will be carried on during this meeting relative to the many and diverse problems now confronting the aeronautical industry.

▸ **Final Programs**—It is expected that, at least by the time this issue of the AERONAUTICAL ENGINEERING REVIEW is in the mails, the final programs for the meeting will have been received by all I.A.S. members. Any other persons desiring programs will please contact Robert R. Dexter, Secretary, Institute of the Aeronautical Sciences.

N.A.C.A. Honors John Jay Ide

At the meeting of the National Advisory Committee for Aeronautics on March 20, 1952, in Washington, D.C., John Jay Ide was honored for his services as the European Representative of the N.A.C.A. for 23 years.

Dr. Jerome C. Hunsaker, Chairman of the organization, which directs the aeronautical research work of the American Government, presented a special gold medal and a scroll to Mr. Ide for having served the Committee "faithfully and with distinction."

Mr. Ide began his work in Europe in 1921 when he was assigned to the American Embassy in Paris. On leave from the N.A.C.A. during World War II, he served in the Navy first in the Bureau of Aeronautics in Washington and later on the staff of the Commander of the U.S. Naval Forces in Europe and as the Assistant Naval Attaché for Air at the American Embassy, London. He returned to civilian life with the rank of Captain, U.S.N.R.

In addition to his work for the N.A.C.A., Mr. Ide has represented the Department of State on many European air conferences such as those of the International Commission for Air Navigation, the Diplomatic Air Law Conferences of Warsaw, Rome, and Brussels, and the International Technical Committee for Legal Air Experts. Since 1922, he has been an American delegate on the Fédération Aéronautique Internationale and is a former Vice-President. He is currently Chairman of the "Commission Sportive Internationale" of the F.A.I.

Honored by N.A.C.A.: *Dr. Jerome C. Hunsaker (left), N.A.C.A. Chairman and I.A.S. Founder Member, Past-President, and Fellow, is shown as he presents the N.A.C.A. gold medal and scroll to John Jay Ide, I.A.S. Founder Member and Associate Fellow.*

Arde Associates Joins I.A.S.

The Institute of the Aeronautical Sciences welcomes as a new Corporate Member the Newark, N.J., firm of Arde Associates.

Arde Associates was organized as a consulting, development, and engineering concern in the aircraft, rocket, and missile fields. However, because of the varied and intensified backgrounds in education and experience of their associates, Arde has since expanded into mechanical, civil, structural, and elec-

Tentative Program of 1952 Annual Summer Meeting

Wednesday, July 16, 1952

8:30 a.m. **Registration**
9:00 a.m. **Morning Session**

AERODYNAMICS

Chairman: Frank E. Goddard, Jr., Jet Propulsion Laboratory, California Institute of Technology
Guest Chairman: L. Eugene Root, The RAND Corporation

Calculation of the Minimum Drag of Lifting Surfaces at Supersonic Speeds—Robert T. Jones, Ames Aeronautical Laboratory, N.A.C.A.
Slender-Body Theory: Review and Extension—Mac C. Adams and W. R. Sears, Graduate School of Aeronautical Engineering, Cornell University
Measurements in the Boundary Layer of a Smooth Flat Plate in Supersonic Flow—Donald Coles, Jet Propulsion Laboratory, California Institute of Technology
Wing-Body Interference Effects on the Tail Contribution to the Damping-in-Roll of Supersonic Missiles—Harold F. Steinmetz, McDonnell Aircraft Corporation

1:30 p.m. **Afternoon Session**

STRUCTURES

Chairman: Walter C. Hurty, University of California at Los Angeles
Guest Chairman: R. L. Schleicher, North American Aviation, Inc.

Statistical Aspects of Dynamic Loads—Y. C. Fung, California Institute of Technology
Effect of Creep on Column Deflections—Tom Higgins, The RAND Corporation
Analysis of Redundant Structures by the Method of Elastic Poles—A. F. Ensrud, Lockheed Aircraft Corporation
Structural Analysis of Swept, Low Aspect Ratio, Multispar Aircraft Wings—Hans Schuerch, Consolidated Vultee Aircraft Corporation

7:00 p.m. **Dinner**

Guest of Honor and Principal Speaker
The Honorable Dan A. Kimball, Secretary of the Navy

Thursday, July 17, 1952

8:00 p.m. **Evening Session**

CONFIDENTIAL DESIGN

Chairman: R. Richard Heppe, Lockheed Aircraft Corporation
Guest Chairman: A. E. Raymond, Douglas Aircraft Co., Inc.

Friday, July 18, 1952

9:00 a.m. **Morning Session**

PROPULSION

Chairman: Edward J. Specht, General Electric Company

Flight Testing and Operational Problems on an Afterburner-Equipped Turbojet Installation—Robert R. Templeton, North American Aviation, Inc.
The Liquid-Coupled Indirect-Transfer Regenerator for Turboprop Plants—A. L. London and W. M. Kays, Stanford University
The Effect of Propeller Control Parameters on Gas Turbine Power Ratings and Flight Efficiency—R. C. Treseder, Aeroproducts Division, General Motors Corporation
The Shock Ignition Engine—Frank F. Rand, Jr., University of Michigan Research Center

1:30 p.m. **Afternoon Session**

DESIGN

Chairman: Robert Jackson, El Segundo Plant, Douglas Aircraft Company, Inc.
Guest Chairman: Carlos Wood, Santa Monica Plant, Douglas Aircraft Company, Inc.

Fundamental Aspects of an Hydraulic-Type-Powered Flight Control System—Harold M. DeGroff, et al., Purdue University
New Components for Air-Frame Construction—Report of Progress—John F. Faulkner and John H. Alden, Aluminum Company of America
Cockpit Design and Safety—William I. Stieglitz, Republic Aviation Corporation
The Airplane Growth Factor and What Can Be Done To Reduce It—Ivan H. Driggs, Bureau of Aeronautics, U.S.N., Washington

Necrology

Margaret K. Gardner

MARGARET KETTLE GARDNER died on March 29 at the Harkness Pavilion, Columbia-Presbyterian Hospital, New York, after a prolonged illness.

Mrs. Gardner will be long remembered by all of us who have been associated with the Institute of the Aeronautical Sciences, for it was through her invaluable assistance during the Institute's early days that her husband, Major Lester D. Gardner, I.A.S. Founder, Benefactor, and Fellow, was able to build the organization of which we are all so proud.

Mrs. Gardner converted her home into the Institute's headquarters during the first year of its existence. It was she who was responsible for the successful execution of many of the myriad details associated with the founding of any organization. Some of the duties she performed so capably included the issuing of invitations to the Founder Members, the subsequent listing of all I.A.S. members, and the maintaining of an accurate set of financial books and statements. For many years after the Institute was established in Rockefeller Center, she continued to give her services gratuitously to the affairs of the Institute.

Through Major Gardner, Mrs. Gardner became vitally interested in aviation. She had her initial contact with the industry in 1915, when she first entertained Orville Wright who became her life-long friend. From that time until her death, she counted among her intimate friends most of the prominent figures in the aeronautical profession.

Beginning in 1926, Major and Mrs. Gardner embarked upon several air tours of Europe, meeting along the way aeronautical leaders of England, France, Germany, and Italy. As a result of these tours, the Institute became international in scope and listed among its Founder Members representatives of both foreign and domestic aeronautical activities.

Mrs. Gardner was born in Angelica, N.Y., on November 18, 1882. For 10 years prior to her marriage in 1913 to Major Gardner, she taught in the New York public schools. She was a member of the English Speaking Union and of the American Legion Auxiliary.

Margaret Kettle Gardner, as she appeared at the Second Anglo-American Conference in May, 1949, with Sir John Buchanan (*left*), then President of the Royal Aeronautical Society, and Major Lester D. Gardner, Founder of the Institute of the Aeronautical Sciences.

A memorial service was conducted for Mrs. Gardner in New York on March 31 by Gill Robb Wilson, who at one time served as a Presbyterian clergyman in a Trenton, N.J., church. Three days later, on April 3, she was buried at Arlington National Cemetery in a site adjacent to the graves of four of America's prominent generals—John J. Pershing, Henry H. Arnold, Muir Fairchild, and Walton H. Walker.

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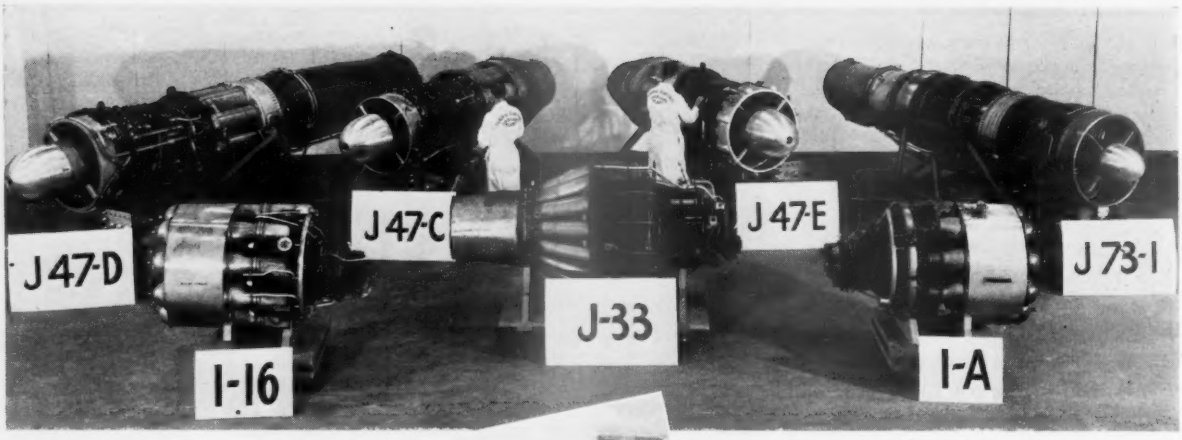
tronic engineering, as well as machine and tool design and jig and fixture work. Arde Associates combines a "top-flight engineering staff, competent design, layout and detail draftsmen," and "excellent test and fabricating facilities" to offer "a complete service, from the development stage to the finished production fabricated item."

Arde claims that its engineers have developed and designed most of the solid propellant booster and sustainer rockets in use today as well as liquid propellant assist take-off units, gas generators, and turbopumps. Development and test programs have been planned, directed, and executed with the objective of producing light-weight economically fabricated rockets. Arde's personnel has also been responsible for certain precision electromechanical devices, control mechanisms, test stands, structural design, and stress analysis in aircraft, rocket, and missile programs.

Currently, Arde is engaged in tool design, jig, and fixture programs for firms in the New York metropolitan area. In addition, Arde is performing long-term development, research, and fabricating work in the aircraft, rocket, and guided missile fields.

(*I.A.S. News*

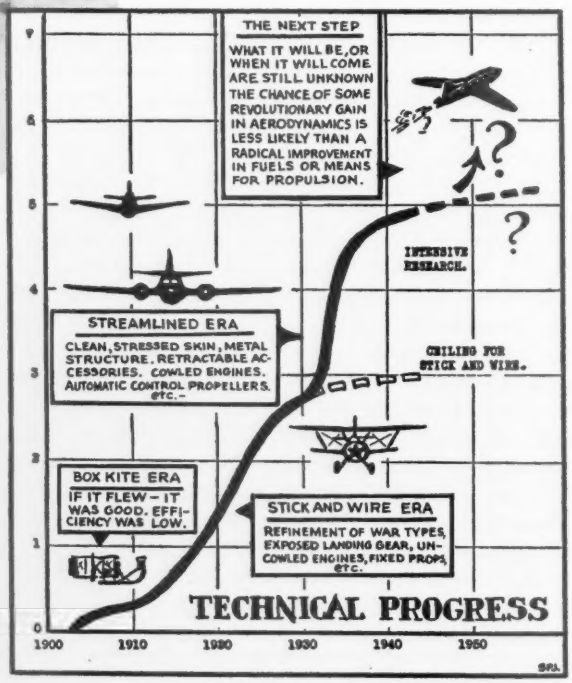
Continued on page 66)



(Above) Evolution of the jet aircraft engine in America is portrayed by these seven General Electric models, the 1-A being the first one built in this country.

(Left) The Bell P-59 Airacomet, America's first jet-propelled plane, was powered with two General Electric built 1-A engines and was first flown in October, 1942.

(Above) America's first jet engine, together with representatives of the organizations responsible for the development, building, and test flying of our first jet-powered plane: Lawrence D. Bell, President, Bell Aircraft Corp., Col. Paul Ney, representing Gen. L. C. Craigie and the Air Force, and Robert M. Stanley, the test pilot.



A QUESTION MARK IN 1944—
A PROVEN FACT TODAY!

(Above) The Technical Progress graph, reproduced from the book Wings After War, by S. Paul Johnston, published by Duell, Sloan and Pearce in 1944, was accompanied by the following caption: "A picture story of aviation progress for the last forty years. The curve has no mathematical significance, but illustrates the trends. In 1944 a distinct flattening is in evidence. How to bend the curve sharply upward is aviation's biggest problem. When that will happen is aviation's biggest question mark."

Editorial

The Fastest Ten Years in History

On March 18, 1942, the first jet aircraft engine to be built in this country was fired-up and tested at Lynn, Mass. That initial jet blast set off a chain reaction that has since changed all concepts of air power in America.

To celebrate the Tenth Anniversary of this event, more than 1,000 top representatives of the aeronautical profession gathered at Lockland, Ohio, March 18–19, to pay tribute to General Electric Company and to the men who built and flew America's first jet airplane. More importantly, the occasion provided an opportunity to review the progress that has been made by all manufacturers of jet engines these past 10 years and to give a little thought to "where do we go from here."

It isn't bad policy to pause occasionally and take a look at where we have been in trying to determine where we are going. The simple little graph, reproduced on the opposite page, gives a pretty good map of the course we have followed. Coincidentally, it was drawn and published just about the time America was testing its first jet-powered aircraft.

A distinct flattening of the technical progress curve 10 years ago is apparent. Reciprocating-engined airplanes, combined with attending knowledge of aerodynamics, were rapidly approaching the ceiling of their performance possibilities. Where we might well be today, if it hadn't been for the turbojet, is indicated by the dotted line. But first the Germans, and then the British, came up with new developments that started us off on another road. Although the direction we were to take is hinted at by the arrow, not even the most optimistic prophet of the day would have forecast the nearly perpendicular line that could be superimposed on this graph at present.

Our little "where-we've-been" chart (published, as you will note, in 1944) also reveals three definite "plateaus," or "peaks," in the technical progress curve. These, in themselves, are historically interesting merely because they record the major design changes in the life of the airplane. Of greater import to us today are the "spurts" in the curve following each plateau. It may shock us out of any complacency we may feel to realize that, in at least two of the three cases, the upswing following each plateau was initiated in Europe.

In the case of the turbojet, which started the rapid climb anticipated by the arrow on our graph, the Germans had a jet-powered airplane—the Heinkel 178—successfully flying in 1939. In 1944, they had the Messerschmitt 262 jet fighter in mass production. But for Hitler's strategic blunders, the Me 262 might well have changed the outcome of the aerial war.

At the close of the war, Russia acquired quantities of the latest German-designed jets, as well as many of the engineers who developed them. Our experiences in Korea would indicate that they have exploited these (and the Nene engine they purchased from England in 1947) to the utmost. There is little reason for us to think them incapable of developing them further.

While we can't take credit for inventing the jet engine, we can surely take pride in what we have done to advance its development. Since October, 1941, when, through the foresight of Gen. "Hap" Arnold, Britain shipped the first Whittle engine to the United States, all of our aircraft-engine companies have done much to keep this technical progress curve on a vertical course.

Where this curve will end in another 10 years is problematical. Our job is to make sure that, when another "peak" is reached, the following upswing of the curve will be the result of American research and development.

W. A. S.

The Turboprop Airplane

WILLIAM W. FOX*

Consolidated Vultee Aircraft Corporation

Introduction

THE TURBOPROP AIRPLANE as we know it today requires somewhat of a transition in thinking from the usual design characteristics of reciprocating-engine-powered aircraft. To date, there have been five turboprop-powered airplanes flown in the United States for an approximate total accumulative flying time of 150 hours. This total is not what might be called impressive considering the time period involved and leads to the obvious conclusion that turboprop engines are still in the embryo stage of their development in the United States. Advancement of the turboprop engine will be aided considerably, however, as we apply the available experience to the solution of our mutual airframe and engine problems.

History

Convair flew the first turboprop powered airplane in the United States in 1945. This airplane was the Vultee Division fighter designated the XP-81. The XP-81 was equipped with a TG-100 turboprop engine in the front of the fuselage and an I-40 turbojet engine in the rear of the fuselage. A total of 47 flights was made with this airplane configuration. Several months later the Ryan XF2R-1 was flown. This airplane was equipped with a TG-100 turboprop engine in the front of the fuselage and an I-16 turbojet engine in the rear of the fuselage. A total of 19 flights was made with this airplane. After approximately 50 hours of total flight time were accumulated between the two airplanes, the turboprop engine developments were discontinued.

Further turboprop airplane operating experience is being gained with a new stable of airplanes that began flying in 1950 using the Allison XT-38 and XT-40 engines. The San Diego Division of Convair first flew the XP5Y-1 airplane on April 18, 1950. To date, 45 hours of flying time have been accumulated in 20 flights. The El Segundo Division of the Douglas Aircraft Company first flew the XA2D airplane on May 26, 1950. The third airplane in this series, the General Motors–Convair Turboliner, was first flown on December 29, 1950. The most recent of this series of airplanes is the North American XA2J airplane, which made its initial flight on January 4, 1952. Within the next several years, many more turboprop-powered

Presented at the Flight Propulsion Session, Twentieth Annual Meeting, I.A.S., New York, January 28–31, February 1, 1952.

* Project Engineer.

airplanes will be flown. In addition, the production Douglas A2D airplanes and the Convair R3Y airplanes will be put into service by the United States Navy in the not too distant future.

Operating Experience

Convair's turboprop operating experience consists of 35 hours with a single-engined airplane, 15 hours with a twin-engined airplane and, at the writing of this paper, 45 hours with a four-engined airplane. In general, it can be said that the same lesson has been learned from all three types of airplanes. Engine failure can be a disastrous situation. The solution to the problem of control of the magnitude and the asymmetry of the approach condition thrust is by no means simple but is necessary to provide proper airplane handling qualities. The basic engine control system must have an extremely high degree of reliability since relatively minor failures can easily result in complete engine failure.

Approach Thrust

The problem involved in the control of the magnitude of approach condition thrust is somewhat unique to turboprop power plants. Normal operation at idle throttle on the low-pitch propeller stop which we are accustomed to in reciprocating-engine installations is entirely unsatisfactory in turboprop-equipped airplanes. This problem is created essentially by requiring a very low propeller blade angle to accommodate the required high idle speed for the turbine. The thrust versus air-speed curve for constant blade angle operation is extremely steep, and, therefore, extremely large changes in thrust occur during a standard landing approach resulting in a severe ballooning or floating tendency in the airplane.

The effect of compressor bleed and other accessory load variations that affect engine power output for a given fuel flow are to increase or decrease the negative thrust for any given airplane speed. A review of the above, as affected by tolerances, indicates fuel flow to be the most serious offender in thrust variations from the desired schedule. Trying to accommodate both AN-F-48 and AN-F-58 fuels is a problem that at the moment does not have a simple solution.

Asymmetric Thrust

One of the most annoying problems encountered on multiengined turboprop-powered airplanes has been the asymmetrical thrust variations during landing or stall approaches at idle throttle position. From the perfection standpoint, symmetrical thrust requires all engines to be operating at equal values of r.p.m., fuel flow, and propeller low-pitch blade angle. All mechanical contrivances must have manufacturing tolerances, and accumulation of these manufacturing tolerances creates the asymmetric thrust problem. Consider this problem in regard to open sea operation of a multi-

Fig. 1. Convair model XP-81. U.S.A.F. turboprop fighter.

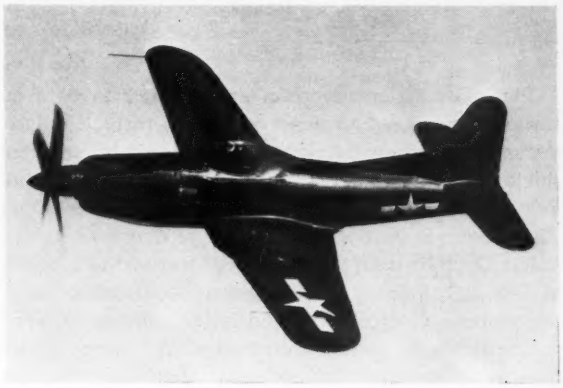


Fig. 2. Ryan model XF2R-1. U.S.N. turboprop fighter.

engined flying boat. The pilot makes his landing approach with a large amount of power at near stall speed. When the sea, immediately ahead of the airplane, is as good as can be expected in the complex sea at hand, the throttles are cut and a full stall landing is made. If the pilot should encounter severe rolling and yawing moments at the point of throttle cutting, loss of the airplane will be the probable result.

Studies made to date indicate that primary asymmetric thrust control will only result from extremely tight fuel flow tolerances for the control systems now in use. Another possible solution to the asymmetric thrust problem is to have the propeller low-pitch stop set at a blade angle that will allow the engine to govern at the desired speed all the way down to the minimum stall speed of the airplane in question without encountering the propeller low-pitch stop. The variations in engine speed and fuel flow are then the only variables in the asymmetric thrust problem. Operation in this manner creates a more severe engine failure problem that must also be solved before the method is due consideration. It must be kept in mind, however, if this solution is to be considered, that the propeller flight low-pitch stop must be set high enough so that a free windmilling propeller will not create an aerodynamic disturbance of unacceptable magnitude.

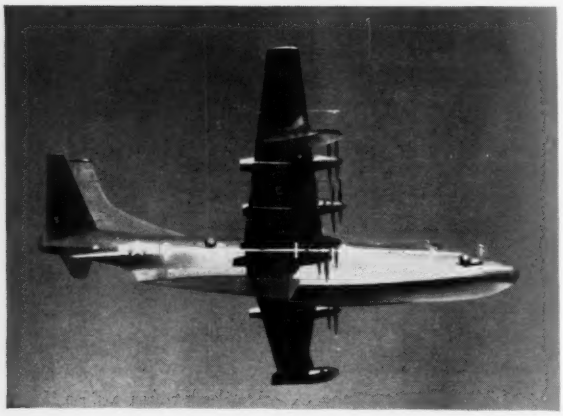


FIG. 3. Convair model XP5Y-1. U.S.N. turboprop patrol plane.

TURBINE FAILURE

The most serious problem encountered to date in turboprop-powered airplanes is that of turbine failure during take-off or landing-approach conditions. In single-engined installations, severe drag conditions and loss of longitudinal control can be encountered from which there is insufficient time for recovery when the failure occurs within a few hundred feet of the take-off or landing surface. Multiengined installations have the problem of directional and lateral control requirements during an engine failure which far exceed those required for reciprocating-engine installations. Another problem that can be classed as an engine failure is that of loss of pitch control on the propeller allowing the propeller to seek flat pitch. Present aerodynamic studies indicate the propeller pitch control failure to be almost as serious as turbine failure even though the possibility of occurrence is probably more remote.

The high drag encountered during engine failure is due to the high motoring power requirement of the compressor and the very low propeller blade angle used for the engine idle condition. In order to meet the engine failure requirements of the Bureau of Aeronautics, a flight low-pitch stop of 25° is required for the Convair Model XP5Y-1 airplane. Since this 25° low-pitch propeller stop cannot be tolerated by the engine in the approach condition, another solution must be found.

Automatic feathering is a possible solution for this problem. If it is used, auto-feathering must provide engine failure protection in both the take-off and landing conditions. The main disadvantage of automatic feathering is the number of pieces of equipment which must function in a serious emergency, or, in all probability, the airplane will be lost.

Automatic decoupling appears to provide the most satisfactory type of engine failure protection. For multiple turbine units it offers the advantage of keeping the maximum number of turbines operating. On single power section installations it provides a simple, direct method of engine failure protection without the unreliability of complication.

Protection for a propeller pitch change mechanism failure must be provided in view of the high drag of a nonrotating turbopropeller in the flat pitch position. A simple pitch lock mechanism seems to offer an adequate solution for the problem.

ENGINE MAINTENANCE

Solutions for the problems mentioned above appear to be forthcoming in the not too distant future. However, the problem of initial setting and maintenance of the engine control system has been time consuming and somewhat grating on tempers. If an attempt were made to put present-day turboprops into field service, the result would be utter chaos. Even the aircraft manufacturers have found that with their skilled experimental personnel and service facilities there are many times when the required tools or intelligence are not at hand. Maintenance procedures are complicated and require the application of electrical and electronic engineers for trouble shooting where commonly shop electricians and mechanics are able to handle the job. Parts are far from interchangeable. The parts that make up a control group for an engine must be tuned as a complete unit; when any one piece is changed, the entire process must be repeated. A great deal of work must yet be done to make the present-day turboprop engine a good service unit.

SUMMARY AND RECOMMENDATIONS

Summing our operating experience seems to indicate that we need to get our turboprops flying to determine whether the pitch lock mechanisms, decoupling mechanism, and fuel control tolerances are in reality solutions for our operating problems encountered to date. Our experience, meager as it has been, would indicate that standard aircraft quality workmanship in electrical harness and "black box" internal wiring will provide equipment with adequate service life. The principal failing in engine control systems to date has been mechanical failure of electrical components. Manufacturing and mechanical design techniques must be developed to provide the type of reliability required for a primary engine control system. A large step must be taken to provide servicing and trouble shooting procedures and check equipment for the engine control systems so that typical aircraft mechanics and electricians can accomplish the task.

Extension shafting problems have been somewhat complex, and the model XP5Y-1 installation has not, as yet, given the type of service expected of a complete power-plant installation. However, modifications are under way which are believed will go a long way toward the solution of our problems. Convair believes that solutions to the extension shaft problems are extremely desirable since it is somewhat of a basic power transmission problem for large airplanes where buried engine installations offer large preformance gains.

The operation of a turboprop airplane is in reality simple when all components function properly. En-

gine run and checkout procedures are extremely simple, and a turboprop airplane can be put into the air in much less time than an equivalent reciprocating-engine-powered airplane. Even though turboprop engines in the United States are in the embryo stage of their development, their future appears to be bright. Continued research and development will provide a type of power plant that far exceeds the capabilities of reciprocating engines and, for some specific tasks, the turbojet engines.

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The Air War in Korea

Gen. Laurence C. Craigie, U.S.A.F.*

"I PROPOSE TO DISCUSS WITH YOU the air war in Korea, its course during the 20 months the war has run, the present situation, and the outlook for the future.

"I will deal almost exclusively with the operation of the U.S. Air Force in Korea, although I will make occasional mention of the other air units. It is important for you to know, though, that the whole operation in Korea has been an example of teamwork. Land, sea, and air forces of many nations—16 to be exact—are participating. The U.S. Navy and Marine Corps have large air units whose activities are coordinated with those of the U.S. Air Force when utilized in the support of ground troops. The Australians and South Africans each have fighter squadrons that operate under the operational control of our Fifth Air Force in Korea. Finally, the Greeks have a detachment of transport aircraft and crews that work with the U.S. Air Force 315th Air Division (Combat Cargo).

"Let us look for a minute back to June, 1950. On the 25th day of the month, after building up their forces to the point where they were overwhelmingly superior to the forces of the Republic of Korea, the Korean Communists struck south across the 38th Parallel. That was the first Communist bid for victory. The force committed was small, but without U.N. intervention it would have been more than sufficient to enable the North Koreans to sweep the Peninsula clear of all organized opposition in a short time. The North Korean Army was well trained and well equipped. It possessed a small Air Force consisting principally of World War II Russian airplanes.

"Had the United Nations coldly stood by, averting its eyes from the death of the Korean Republic, the first Communist bid for victory would have been a successful one.

"About 3 weeks after the Korean War started, I made my official call on General MacArthur. During our conference, General MacArthur commented on the progress of the war up to that time and said, with reference to our entry into the war, that in his opinion the decision of President Truman to resist aggression in Korea would eventually be considered one of the truly great presidential decisions. It was certainly a courageous decision, because the troops in Japan were not prepared or equipped for the operation in Korea. It was a momentous decision, because it enabled the United Nations organization to accept the challenge that was inherent in the Communist aggression in Korea. If the challenge had been ignored, the United Nations would have been finished insofar as the Far East was concerned. This decision, then, gave the United Nations an opportunity to gain the stature which it must acquire before it could hope to discourage aggression throughout the world. It was fortunate for the overall peace of the world that the United States, in concert with the other United Nations, acted as, and when, it did. Long term chances of achieving world peace were certainly enhanced by this U.N. action.

"First into combat went our air and naval forces in the Far East. Then, as rapidly as possible, our small Army of Occupation in Japan was deployed across the Korean Peninsula in front of the advancing Communists. Within a few weeks, our air power had destroyed or damaged more than 150 enemy aircraft, and the North Korean Air Force was eliminated as an effective combat weapon. Even so, the enemy's initial attack had been rolling fast before our ground forces got into the line, and the very momentum of the enemy's drive carried him almost to within sight of his objective.

"The initial employment of our ground forces in Korea broke all the rules in the book. Piecemeal commitment of one's forces is in violation of the sound and proved principles of warfare. It had to be done in this case, though. We knew we had more troops and equipment coming, but they were not there then. Our problem, the problem of the ground forces and the air and naval forces, was to stop the advance south of the Communist forces until we could get into play both the troops and equipment that were en route. As a result of committing our forces piecemeal, we

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* Deputy Chief of Staff—Development.

caused the Communist forces to deploy, and their advance to the south was slowed greatly. We were able then to get our additional forces and our additional equipment to Korea in time.

"As the perimeter that we held shrank day by day, the map, as you will recall, looked worse and worse. There were only a few bright spots. Bill Dean and his gallant and courageous 24th Division almost held at Taejon, about 60 miles northwest of the line on which we finally held. But the North Koreans were able to build up their forces and finally break through. Bill Dean himself was taken prisoner. Hap Gay brought the First Cavalry Division ashore at Pohang-dong and was in the fight almost immediately. The 25th Division was, of course, in it even before the First Cavalry. The Marine Brigade contributed magnificently to the Nak-tong perimeter stand. As we watched that perimeter get smaller, one word was in the back of almost every mind, but it was almost never spoken. That word was *Dunkirk*.

"Korea is a large country. It is actually 700 miles from Pusan up to Rashin, in the northeast corner, and it is 400 miles from Pusan up to Antung, at the mouth of the Yalu river on the Manchurian border in the northwest corner. What looked like a very small perimeter on the map (and, of course, it was small on a newspaper map; only a column or two wide) actually, when translated into miles, was not too small. The line never got shorter than approximately 120 miles. It extended from the East Coast by Pohang approximately 50 miles to the west around and then down the Nak-tong River to the Tsuchima Straits. The length of our line was one of our troubles. We did not have enough divisions to hold a line any longer than that. We had to pull back until our forces would fit a line that we could defend.

"The South Korean divisions at that time—remember the South Koreans took a terrific lacing the first few days of the war—were relatively untrained. Anti-tank ordnance was not yet available, and, even more important, we had not yet learned to cope with the enemy's night infiltration tactics. So it was nip and tuck. The North Koreans could smell Pusan and victory, and they fought like the very devil. The U.N. forces were beginning to gain confidence, however, as their armor and additional troops continued to arrive in Korea. So, around this Nak-tong perimeter our forces regrouped and held.

"Against the Nak-tong perimeter the force of the enemy attack finally spent itself, and, under the growing weight of our combined air, land, and naval pounding, his forces began to crumble. It turned out that he was taking quite a gamble. He could see victory in sight. He was stretched much too thin. He did not have the necessary reserves, so when we finally broke through, our advance to the north was spectacular. The Inchon landing occurred at that time, the middle of September. It was a most difficult operation and one that was planned and successfully executed only because we held absolute supremacy in the air and on the sea. Otherwise, it would not have been possible. As a result of the Inchon landing, the enemy's position was made absolutely untenable. He raced north in disorganized retreat. His army disintegrated into small bands no longer in communication with one another. The enemy had definitely lost his first bid for victory.

"But the Communists, as we are beginning to see demonstrated more and more convincingly, are a flexible, persistent, and determined breed. After the North Korean Army had been routed and dispersed, they made a second bid for success, and this time the bid was higher. Across the Yalu came Chinese Communist armies in overwhelming strength. Before the relentless surge of this human sea, our forces retreated to Seoul and beyond. We fought another delaying action, which was not really stopped until we had retreated to a line approximately on the 37th parallel of latitude. This constituted the high-water mark of the Chinese Communist advance.

"Once again, this time in February, 1951, we reversed the direction of movement, and the United Nations Command forces started to push the Commies back. Three times the Communists staged large-scale offensives in an effort to stop the United Nations Command advance. We suffered many casualties as a direct result of each of these Communist offensives, but the enemy's were many times worse. Each of these offensives was followed by a counter-offensive by the United Nations Command, which pushed the enemy back substantially north of the line from which he started his offensive. In this action he was forced out into the open during hours of daylight, and he suffered extremely heavy casualties. Then, the armistice discussions were initiated, and ground action slowed down.

"Since June, there have been no major offensives extending across the entire front, although almost continuous pressure has been exerted against the enemy across the central and the eastern front.

"But, prior to the armistice talks, the Commies had already been pushed north of the 38th Parallel along most of the battle line. Our troops were acquiring good defensive positions. I think it is not too much to state that at that point the Communists lost their second bid for victory. Victory seemed farther from their grasp than at any time since the first weeks of the struggle.

"Looking back on all that transpired up until the fall of 1951, it seems really extraordinary that the Chinese should have committed their ground forces unstintingly while withholding from combat all but a few bits and pieces of their Air Force. The example of the fate of the North Korean Army was before them, but they chose to ignore the lesson.

"In the meantime, our new air bases in South Korea were progressing nicely. New light bomber and fighter units were arriving in Korea. Three wings of B-29's

were operating from island bases so situated that these medium bombers were able to range easily to the northernmost portions of Korea. They could carry full bombloads on the longest missions. It is of interest to note, I think, that within 4 days of being ordered into action one of these groups departed from its base in the United States and entered combat in Korea.

"As early as 15 months ago, while the United Nations Command Army was still retreating, we knew that the Chinese Communists were building a jet fighter force just as rapidly as they could. It would appear that they realized that where a primitive mass army could be gambled in a bid for victory with some hope of success, an obsolete air force could not hope to live in the same skies with modern air power.

"At this stage of the war, a few jets, the now notorious MIG-15's, were beginning to appear on the airfields just north of the Yalu, in the Antung area. Their initial operations were confined to a defense of the Yalu River bridges against the attacks being staged then by our B-29's. These MIG's were troublesome only along the Yalu—along 'MIG Alley,' as our pilots called the airspace just south of the river valley. They never ventured far from their Manchurian sanctuary to challenge our increasingly effective bombing and strafing of Communist troops and supplies which were taking place the length and breadth of Korea.

"As we have seen, by midsummer of 1951, a relatively stabilized line had been achieved on the ground. Our forces had won the defensive positions they wanted as a result of a great deal of good hard fighting. And with a crisis on the ground once more past, air power was no longer needed to the same extent as it had been before to conduct emergency operations in support of our hard-pressed troops. It thus became possible for us to commence, systematically and on an extensive scale, a form of air attack designed to prevent the enemy from regaining his offensive power.

"The type of operation we proposed was not new. We had employed it in World War II, with striking results. In Italy Gen. Mark Clark's offensive in 1944 was preceded by an air interdiction program that had continued throughout the winter. The rate at which the German armies were supplied steadily diminished from 80,000 tons a day to an estimated 4,000 tons a day. When the Allied offensive got under way in May, General Clark wired the Air Commander, General Cannon: 'Greatly pleased with the splendid efforts of the Air Force. We have put the enemy on the road. Good hunting to all.' And as we know, the hunting *was* good, and 'Operation Strangle' paid off many times over.

"In recollection of this earlier campaign, the one that began just seven months ago, in August, 1951, was called 'Operation Strangle (Korea).' This new program was carefully planned and executed to exploit the dependence of the Chinese upon supplies from China and Russia brought to the front by rail and road. A massive attack was begun upon the railroad system from Manchuria into North Korea. At that time the Chinese had more than 50 divisions, requiring daily movement of more than 5,000 vehicles and of as many locomotives and boxcars as they could get on the road. Our sustained round-the-clock attacks were able to destroy scores of locomotives and hundreds of railroad cars during the months of September and October. And of the thousands of trucks that the enemy was forced to operate, we were able to average better than 180 destroyed every 24 hours. But this is not all the damage we caused him. We estimate that the enemy, in his efforts to avoid destruction by driving at night and on by-pass routes, wrecked or wore out about 100 vehicles a day during the same period.

"Let us examine for a moment the geography of 'Operation Strangle.' The most direct and economical route from North Korea runs from the Yalu down toward Seoul. Down the western corridor the enemy has two and, in some places, three railroads at his disposal. It is along these routes that most of his supply effort has been concentrated. Here, our attacking planes have found the greatest number of targets. There is another rail line down the East Coast through Hungnam to Wonsan. Much of this line is within range of naval gunfire, and an effective combination of naval and air forces has greatly restricted its use by the enemy.

"Most of the rail lines in Korea are paralleled by roads. In addition, the enemy has developed a system of secondary roads. Both classes of roads are utilized for his truck traffic. As the attacks on the enemy rail system became more constant, the Communists turned more and more to road transportation, which, of course, is slower and more costly. The scale of his trucking efforts may be judged from the fact that our aircraft sighted a total of more than 75,000 vehicles in October, an average of 2,500 a day. The nightly count sometimes ran as high as 9,000. For the last 100 miles of his supply system the enemy is entirely dependent on movement by truck rather than by rail, as a result of the destruction of rail facilities south of Pyongyang. Of course, he has been badly hit to the north as well.

"I should also mention that there has been a tremendous concentration of antiaircraft installations along the main supply routes. In short, the enemy has been obliged to commit more and more of his military strength and equipment of all types in order to move a minimum of supplies to his armies at the front.

"An important feature of 'Operation Strangle' is its carefully planned regularity and the continuous pressure which it maintains. When used in this manner, air power is able to exert constant and destructive pressure on the enemy well back toward the sources of his supply. This destructive pressure from the air can be as relentless as the pressure exerted by our ground forces against his front-line troops.

"It soon became clear to the enemy that his was a losing position. He no longer possessed the means to sustain an offensive on the ground. Our well-supplied troops were looking down his throat from superior

positions. If he were merely to maintain his position on the ground, he would have to stop, if he could, the continuation of 'Operation Strangle.' There was only one way to do this. He would have to commit the air power which he was hoarding behind the Yalu. No one in the free world supposes for a moment that the Chinese have built their own air power. The equipment with which they are fighting in the air over Korea is a gift of the Soviet Union. In the fall of 1951, with U.N. air power taking a mounting toll of Chinese battle equipment, the Soviet Union became even more liberal with its air power than it had been in the past.

"For a third time the Communists made a bid for victory. 'Operation Strangle' was but a few weeks old when MIG's in increasing numbers began to appear well south of the Yalu.

"Now, just a word about the size of the Chinese Communist Air Force. We know that they have deployed in North China and Manchuria more than 1,400 airplanes, of which about one-half are MIG-15's. It is also known that about one-half of the MIG-15's are positioned just beyond the Yalu and that there is a rotation of units in and out of this area. The number of MIG's sighted during the summer was running between 300 and 400 a month, an average of 10 to 15 a day. Then in September the number leaped to 1,400, an average of 40 or 50 a day, and in October to 3,000, an average of 100 a day. This represents an 800 per cent increase over the summer average. Subsequent sightings increased over the number reported for October. Apparently, this increase in MIG-15 activity was a direct result of 'Operation Strangle.' Obviously, this new and heavy concentration of MIG's in a small section of North Korea interfered to some extent with our interdiction campaign in that area. On several occasions F-84 fighter bombers attacking the railroad between Sinuiju, up in the far corner, and Sinanju, 80 miles southeast, were forced to jettison their bombs in order to defend themselves from MIG attacks. It became necessary for us to devote a higher percentage of our total air effort to counter these MIG attacks.

"Correspondingly, our logical answer to this was to decrease our interdiction effort in the extreme northwest, while increasing our counter MIG operations in that area, and concentrate the weight of the interdiction in the area south of the Chunchon River. The Chunchon River is parallel to the Yalu, about 80 miles southeast of it. While this change reduced the effectiveness of our interdiction campaign somewhat by narrowing the choice of targets, a major result was to intensify this United Nations Command interdiction program in the section from Pyongyang to Sinanju. The punishment of Communist transportation vehicles continued unabated.

"The next move was up to the enemy. Although he had by this time committed a high percentage of his fighter strength and had interfered with our interdiction in one area, he had not greatly reduced the effectiveness of 'Operation Strangle.' To do that, he would have had to extend the heavy concentration of MIG activity further to the south, and he could have done this most effectively by operating from bases within Korea. There is a great advantage to be derived from fighting within sight of one's own bases against attackers who must approach from a great distance. It was possible for the Communist planes to rise in full strength to meet our formations approaching the Yalu from the south. But, when our missions did not extend beyond the Chunchon River, the enemy had to depend for his defense on MIG's that happened already to be in the air. If he could have established new bases near the Chunchon, he would have been able to advance nearly 100 miles with tactical advantages that he enjoyed in the vicinity of the Yalu. This is precisely what he tried to do during October, November, and December of 1951.

"At Antung, just across the northwest border of Korea, is a complex of jet bases from which the MIG's are now operating. About 100 miles to the south are three fields that could be developed into MIG bases. These three are Taechon, Namsi, and Saamcham. I should note in passing that there are close to 100 airfields in North Korea available to the Chinese Communist Air Force, but only a few are potentially suitable for jet operation.

"In September of last year it was discovered that the three particularly large airfields that I named a moment ago were being expanded and improved with amazing speed. It was evident from their dimensions and the type of construction that they were intended for jet use. And, since they were all located within a 20-mile radius, it was apparent that a concentrated defense of these fields by the enemy would be possible. Moreover, during the course of the construction, the enemy moved in strong antiaircraft defenses, providing further evidence of his determination to make a heavy investment in that area. The speed with which these airfields were developed during the month of September indicated the urgency that was attached by him to the project. During the third week of October, our bombers attacked two of these airfields in rapid succession. Although antiaircraft was intense and we lost one of our bombers, we did not encounter any fighters on those two attacks. Then, on October 23, we struck at the third field, Namsi, and, here, we met with violent and desperate resistance on the part of the enemy. The MIG attacks were pressed home in a more determined fashion than they had ever exhibited before. Some enemy planes passed directly through the bomber formation. One hundred and fifty MIG's were thrown into this fight, which lasted approximately 30 min. Although we destroyed three MIG's—and we probably destroyed one more and damaged an additional eight—we ourselves suffered the heaviest loss of any single action in the Korean War. Because we only had a small bomber formation involved—and a small formation is inherently weak on defense—and because our escorting fighters were heavily outnumbered, three

bombers were shot down, while the remaining five were damaged.

"Despite the strength and severity of the MIG attack, however, the mission was completed. This fight marked the beginning of a week of violent air battles. For 7 straight days our formations in North Korea encountered flights of more than 100 MIG's. By the end of the week we counted 12 MIG's destroyed and 28 additional MIG's damaged. In addition to those lost in the first day's battle, we lost during the week two medium bombers and suffered damage to three more. We also lost four fighters and had two others damaged.

"Shortly after this B-29 attack, which I just discussed, another B-29 formation returned to that same area and succeeded in destroying an extremely important bridge target. On this occasion, however, we had many more airplanes present in the air (fighters), and no bombers were lost.

"In view of the extremly heavy defense of the area between the Yalu and the Chunchon and because there were no targets in North Korea of sufficient size to justify large formations of medium bombers, which would be stronger defensively, it was decided to shift our medium bomber effort to individual attacks, principally at night. These single attacks have proved effective, and so far the enemy has been unable to repair and use the three critical airfields.

"It should be remembered that to make full use of these airfields, even if he should succeed in maintaining them, the enemy must be able to mount an effective air defense over the surrounding area. He cannot do this as long as our F-86's continue to challenge his MIG formations. If, on the other hand, he can establish control of the air in the vicinity of these fields, he would be able to use them to our great disadvantage. He could then challenge our F-84's and other planes on interdiction missions anywhere in North Korea.

"The enemy has apparently abandoned his efforts to establish MIG bases south of the Yalu. Our F-86's, almost always greatly outnumbered, have been able to more than meet each challenge by the MIG's. That is the significance of the air battles in Korea. Our top-heavy score of MIG's shot down is not the measure of our success. The important fact is that the MIG's are kept occupied by our Air Force fighters; meanwhile, Air Force and Naval operations against enemy transport and equipment on the ground have continued without serious interruption. The most recently released figures show that in 6 months of operation Fifth Air Force tactical light and fighter bombers have made more than 16,000 cuts in rail lines, destroyed and damaged 470 locomotives, 10,400 rail cars, many of them loaded to capacity, destroyed or damaged 955 bridges, and damaged 180 tunnels. Fifty Communist tanks were destroyed and 50 more damaged. Approximately 27,500 vehicles, used to supplement a tottering rail transport system, have been destroyed. More than 265 supply, ammunition, and fuel storage dumps were fired and exploded. Twelve thousand enemy supply buildings were destroyed and 16,700 damaged. Meanwhile, close air support to U.N. ground forces continued, inflicting thousands of casualties on Red soldiers and silencing 2,000 enemy gun positions.

"Weather and the phase of the moon can cause fluctuations in the strength of our air operations and in their effectiveness. Despite winter weather, however, and despite persistent snow-cover that enables the Reds to operate their vehicles without lights on nights when there is any moon at all, we are maintaining the pressure from the air. Reports from Tokyo covering Far East Air Forces' activities during the past few weeks show that on an average Air Force and Navy aircraft have been destroying between 80 and 90 enemy vehicles each day. We are extending our interdiction attacks farther northward, cutting the rails at more than a thousand points each week. The enemy has been committing reckless numbers of his locomotives to emergency repair work and suffering high losses as a result. During the past month he has lost outright between 30 and 40 locomotives and suffered damage to more than half again this number.

"The fact that we are once again able to hit the enemy supply routes just south of the Yalu in round-the-clock operations is attributable to the effectiveness of the F-86 against the MIG. Which is the better aircraft? The question is being asked today in many quarters. Compare their performance data, and the MIG seems to have the edge. It is a lighter airplane, with a greater rate of climb and a higher ceiling. It is slightly faster at altitude. Its engine is somewhat more powerful than the 5,200-lb. thrust J-47 in the Sabre. It has two 23-mm. cannon and single 37-mm. cannon. The Sabre has six 50-caliber machine guns. It fires a heavier projectile which, furthermore, contains a high explosive charge.

"And yet, despite the fact that the F-86's have been outnumbered by the MIG's five and six to one in the skies over Korea, the F-86's are winning the air-to-air battles. The box score today of confirmed kills gives the F-86's an eight to one advantage. The question, of course, is 'why.'

"In my opinion, three factors are responsible for our success. First, our pilots are better. I grant you that it is hard to make an objective comparison, but time and again a pair of 86's will barrel through two or three flights of MIG's, knock a couple off, and escape without damage. That kind of performance takes skill, nerve, and aggressiveness. Our pilots have all three.

"Second, the F-86 is a better flying machine than the MIG. This fact is reflected in its better stability and control characteristics at very high speeds. The F-86 can overtake the MIG in a dive and either shoot it down or force it to crash out of control. For the same reason an 86 with a MIG on its tail can dive away to safety.

"Third, the F-86 has a better gun sight, and its six 50-caliber machine guns can concentrate more lethal fire power with less dispersion at greater range

than can the MIG's cannon. What is more, 50-caliber ammunition takes up far less space than cannon projectiles. Our pilots often have plenty of fire-power left when the Commies have run out of ammunition.

"In view of the licking they have been taking, it is small wonder that the Reds have been doing a lot of flying in the past months at 40,000 ft. and higher where they can fight on more favorable terms. It is plain, however, that as long as the MIG's stay high they will not bother us much. Their mission is defensive, and as long as they will not come down to tangle with our fighter bombers, we do not mind their boring holes in the air 8 miles up. During the past week, though, our penetrations above Chongju have brought the MIG's down. And, as all of you know, the F-86's, riding herd on the fighter bombers, went after the MIG's and shot them down in numbers that are large for this war—seven on Tuesday and six on Wednesday. The fighter bombers completed their missions undisturbed.

"So it appears that the enemy's third successive bid for victory has failed. His attempts to stop 'Operation Strangle' through the defensive use of his air power have not paid off. Given the present situation, it seems obvious that the Communist enemy in Korea must either decide upon peace or make a fourth and higher bid for victory by throwing in new forces. It is just as obvious that an offensive air force offers the best solution to this problem. In this connection it would be well to remember that while we have refrained from attacking targets in Manchuria or China proper, the enemy air force has similarly refrained from air attacks on our troops and air bases in Korea. In other words, while we have carried out a vigorous air offensive clear to the Yalu, the enemy has never seriously taken the offensive in the air. Certainly he has not refrained from doing this out of any sporting regard for the restrictions under which our operations must proceed. He has refrained, in my opinion, because he fears our power of retaliation.

"The Korean War, while extremely expensive to the Chinese, has also been extremely costly to Russia. By any standards, the Soviet air power investment, in terms of materiel and technicians, must be enormous. The battle losses and the inescapable operational expenditures of Russian-built aircraft are already considerable. In addition, the destruction on the ground of Soviet-supplied transport and other war materiel has constituted a serious drain on the Russian armament program. If, despite these heavy expenditures, the war goes on and the enemy is able to maintain it at the present level, we are clearly in for a hard and bitter fight in the air.

"Of the final outcome I have no doubt. We, too, are continuing to increase our air investment in this war, and I know that if still more is needed a way will be found to supply it. American workers and industry will, I am sure, meet the emergency and will supply us with air equipment of superior quality and in sufficient quantity. In the meantime, we must continue to depend upon the superior ability and determination of the fighting airmen of the Far East Air Forces, the United States Navy and Marine Corps, and the other United Nations Command Units, the Royal Australian Air Force, and the South African Air Force.

"Therefore, as the United Nations Army holds its high ground in Korea, and as the truce talks at Panmunjom proceed, the pressure of our air power continues to exert itself upon the Communist enemy and continues to persuade him that a peaceful solution in Korea is to be sought. The world knows where the United Nations and our own country stand. We stand for peace. If the enemy also decides for peace, then the welfare of mankind will be served. Should he decide for war, he must bring with his decision the force required to back it.

"Before closing, I must speak a warning. Air interdiction is a potent military tactic, but no matter how effectively it is carried out, some supplies will get through to the front. This is particularly true where the enemy can augment his mechanized transportation system with untold thousands of human carriers. Despite the success of 'Operation Strangle,' the enemy is able under the circumstances of a stabilized front to add to his store of materials little by little. The reason for this is that fewer supplies are required when the fighting is at a low level. We must remain vigilant and prepared at all times. Should the enemy decide to commit to the war an offensive air force, he would certainly coordinate such an action with offensive action on the ground.

"I would like to leave this thought with you. Ever since World War II, the Russians have invested heavily in the design and the production of aircraft. Highest awards and honors have been showered upon those who have been successful in this field. The accelerated development of the Red Air Force has become a major project within the Russian military services. It holds a high priority for personnel, materials, and talents. Russian propaganda has boasted loudly of Soviet achievements in air power. Public celebrations and displays within Russia have demonstrated the overriding importance that the Soviet Government attaches to emphasis upon the building of Russian air power. In Korea there have been disclosed to us the fruits of this concentrated and intense effort. It holds a sobering lesson for all of us, although that lesson is a simple one. It is this: that not even the most powerful industrial nation on earth, nor the people with the highest technical gifts, can expect to maintain, without continued strenuous exertion, their advantages against the powerful drive of a supposedly backward nation that is determined to overcome its handicaps regardless of cost and sacrifice. The Russians have grasped the real meaning of the revolution in military strategy brought about by the development of air power. It is obvious that they do not intend to accept the frustration of their world-wide aims which our superior air atomic power has imposed upon them since

(*Continued on page 40*)

Functional Cockpit Design

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MEASUREMENTS OF MAN PROVIDE specifications for functional cockpit design. The success in satisfying human requirements in any design or work situation will determine, to a considerable degree, both the safety and overall efficiency of the operating personnel. It is probable that, in the majority of cases where design deficiencies in fitting the cockpit to man exist, the errors have resulted not from the lack of the designer's concern for man, but rather from the lack of adequate descriptions of man's physical characteristics, of the biomechanics of his body movements, and of his physiologic and psychologic capabilities.

The specific purpose of this report is to bring together data that may serve as a partial basis for functional design and to discuss some of the problems in their application. Part of the material that has been previously reported is included to permit its integration with new data that have not been published before. Discussion will be limited to physiological and anatomical descriptions necessary for satisfying some of the general human requirements for any working space. These are: (a) provisions for visibility and their relation to what man is capable of seeing, (b) arrangements for the efficient operation of controls as determined by static and dynamic body measurements, and (c) provisions for a stable platform of operations so that the pilot can maintain his seated position in the cockpit with minimal effort under normal and emergency conditions, including crash and decompression resulting from structural failure.

SOME GENERAL COMMENTS ON PROPER SELECTION OF VALUES FOR APPLICATION TO ENGINEERING DESIGN

There are two major considerations in the selection of specific measurements of man for use in engineering design. First, it is essential to use biological descriptions that are directly applicable to the work situation. Second, it is essential to select values that will be satisfactory for a large percentage of potential operators.

Pertinency of Measurements

Data on man which will be pertinent to functional cockpit design must be taken under conditions that parallel those of normal operation or function. Many of the body measurements that are made in accordance with conventional anthropometric techniques or under conditions used for specifying sizes of clothing are unsatisfactory for determining dimensions of a work space. Pilots assume the rigidly standardized positions for anthropometric measurement only when serving as subjects for an anthropologist and not while operating an airplane. It is in no way the fault of the investigators who have developed measurements for an entirely different purpose that attempts are made to use their results in situations where the data are not applicable. In cases where the anthropologist has undertaken the solution of a structural design problem, his recommendations have resulted in outstandingly successful arrangements as evidenced by the studies of Hooten, Randall, Damon, Hertzberg, and others. Similar limitations exist in the application of certain medical measurements, as will be noted in the discussion of visibility.

Values Satisfactory for the Pilot Population

The second general consideration—that of determining the adequacy of any selected measurement in providing for the population of men who will operate the equipment—is of utmost importance. Average values are applicable only in special cases where the objective is to provide for simultaneous use by a group of people rather than arrangements for individual use, as in the case of a pilot or flight engineer station. For example, the average value for body weight can be used as a basis for specifying strength requirements for a structure supporting a group that, theoretically, should number 30 or more people. It may also be used when establishing somewhat arbitrary criteria for evaluating a design in relation to its provisions for utilizing total (average) human capability, especially where practical limitations preclude full attainment of such an optimal condition. Here it serves as a theoretical limit of achievement and a measure of the extent of the compromise that it is necessary to make.

In designing for individual use, the average value cannot be used directly since, by definition, arrangement of a flight station or work place based upon an average would be unsuitable for 50 per cent of the operators if the measurements have a normal statistical distribution. Provisions satisfactory for 90 or 95 per cent or for any other desired proportion of the pilot population will require identifying the correct cutoff points. Some arrangements require selection of a value near the upper limit of the range of measurements; others will require use of near-minimal values. This approach to selection of appropriate values will be illustrated during discussion of some of the quantita-

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tive descriptions of man presented in subsequent sections of this report.

Visibility

Pilot's Eye Position

Eye position is an essential reference point for vision and for most, if not all, other aspects of the functional design of a work space.

Eye level has been measured on a perpendicular rising from a seat reference point. The seat reference point was taken as the midpoint of the horizontal seat member at the intersection of the upper level of the (undeformed) seat cushion and the forward surface of the back pad. On the basis of available data (Table 1), we may expect that the eye level of a high percentage of any pilot population (theoretically 95 per cent, if values are normally distributed) will lie between 27 and 34 in. above the seat reference point level when men are seated in a normal operating position.[1] Values for both eye level and sitting height when maintaining a natural easy sitting position are about one-and-one-half to two inches less than when measured under the standardized (and sometimes artificial) postures used by anthropologists for comparison of races and groups.[2, 3]

The other values that would be necessary to locate eye position in the cockpit are not determined by body measurements. Distances from the windshield and to the right or left of the longitudinal axis of the airplane are imposed by interior arrangement and at present show considerable variation in different aircraft. The significance of these distances will be considered in a later section of this report.

Man's Area of Vision

Data on "what man can see" provide a basis for comparing the boundaries determined by limitations of human capacity for seeing and the limiting boundaries imposed by structural design. The objective here is to give the design engineer quantitative information on a human capability; that is, to describe *the total expanse of space which a pilot would see from his operating position if no visual obstruction were present.* Areas of vision are stated in terms of angles subtended along various meridians or visual axes in order to be generally applicable. Just what a pilot can see in any particular situation will, of course, depend upon his position

Table 1

Sitting Height and Eye Level (in Inches) of Men Measured in Anthropometric and Natural Sitting Postures[1] ($N = 100$)

	$\bar{x}$‡	$\pm s_{\bar{x}}$	$\pm s$
Anthropometric* sitting height	36.20	0.132	1.32
Natural† sitting height	34.79	0.125	1.25
Anthropometric* eye level	31.32	0.126	1.26
Natural† eye level	29.66	0.124	1.24

* Standard anthropometric technique.
† Measured in natural easy sitting posture.
‡ x = mean, $\pm s_{\bar{x}}$ = standard deviation of mean, and $\pm s$ = standard deviation.

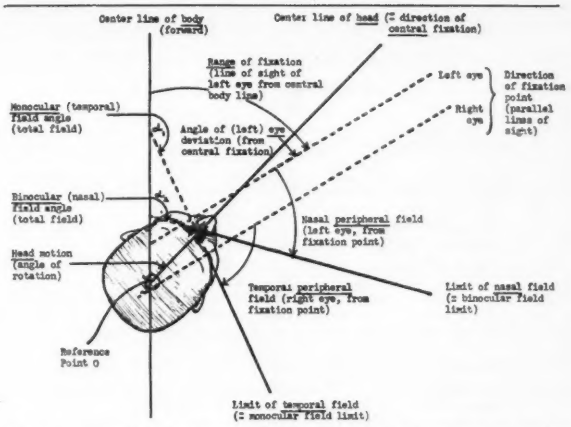
Center line of body (forward)
Center line of head (= direction of central fixation)
Range of fixation (line of sight of left eye from central body line)
Left eye
Right eye
Direction of fixation point (parallel lines of sight)
Monocular (temporal) field angle (total field)
Angle of (left) eye deviation (from central fixation)
Binocular (nasal) field angle (total field)
Nasal peripheral field (left eye, from fixation point)
Head motion (angle of rotation)
Temporal peripheral field (right eye, from fixation point)
Limit of nasal field (= binocular field limit)
Reference Point O
Limit of temporal field (= monocular field limit)

Fig. 1. Showing horizontal field angles and other angular ratios (scale about 1:4).

in the cockpit and upon the degree of freedom of movement permitted him.

Measurements of field of vision are frequently made in medical examination of the eyes, so that it might be expected that well-established values would be available as reference material in considering visibility. These medical measurements, however, are made under conditions quite different from those associated with airplane operation. For perimetry, the subject leans forward with his head firmly fixed on a headrest with one eye covered, while the other eye is focused on a point directly forward. The boundaries of the areas that could be viewed when the eye is looking to the right or left cannot be predicted from knowledge of the form field with the eye in mid-position plus the degree of eye movement[4] (see footnote *** in Table 2).

About 2 years ago, we made a critical survey of the scientific literature to summarize the values that have been reported for the form and color fields.[4] Since Hall and Greenbaum were unable to find data on viewing under natural conditions of eye movement, they carried out new measurements on a few subjects to determine form fields when the eyes were deviated from their central position. Data reported by these investigators are presented to show the areas that can be scanned under the conditions of conventional medical examination and under several conditions of head and eye movement; values for the extent of head and eye movement of which man is capable are also shown (Table 2 and Fig. 1).

Any of the several conditions would serve for the purposes of the present discussion. Eye movement 15° to the right, the left, upward, and downward from the mid-central position was selected as one standard condition for viewing on the basis of Bielschowsky's statement that fixation points do not usually vary more than 13° to 15° from the point of central fixation when performing everyday visual tasks.[9] Head movements of 45° to the right and left and 30° upward and downward, which are performed easily and naturally, were selected as the other standard condition in establishing a functional visual reference area. These moderate

TABLE 2
Field Angles of Human Vision[8]

Condition of Movement Permitted	Type of Field	Horizontal Field (Temporal) Monocular Limit (each side)	Horizontal Field (Nasal) Binocular Limit (each side)	Vertical Field Limit of Field Up	Vertical Field Limit of Field Down
(a) Head and eyes: moderate movements, eyes 15° R, L, U and D head 45° R and L 30° U and D	Range of fixation	60°		45°	
	Eye deviation	15°	15°	15°	15°
	Peripheral field from point of fixation	95	(45°)	46°	67°
	Net (peripheral) field from central fixation	110°	60°***	61°	82°
	Head rotation	45°	45°	30°*	30°*
	Total peripheral field (from central body line)	155°	105°	91°	112°**
(b) Head fixed eyes fixed (central)	Peripheral field (central fixation)	95°	60°	46°	67°
(c) Head fixed eyes maximum deviation	Limits of eye deviation (= range of fixation)	74°	55°	48°	66°
	Peripheral field from point of fixation	91°	Approx. (5°)	18°	16°
	Total peripheral field (from central head line)	165°	60°***	66°	82°
(d) Head maximum movement eyes fixed (central with respect to head)	Limits of head motion (= range of fixation)	72°	72°	80°*	90°*
	Peripheral field (from point of fixation)	95°	60°	46°	67°
	Total peripheral field (from central body line)	167°	132°	126°	157°**
(e) Head and eyes: both maximum movement	Limits of head motion	72°	72°	80°*	90°*
	Maximum eye deviation	74°	55°	48°	66°
	Range of fixation (from central body line)	146°	127°	128°	156°**
	Peripheral field from point of fixation	91°	Approx. (5°)	18°	16°
	Total peripheral field (from central body line)	237°	132°	146°	172°

* Authors' estimate based on tests on a single subject.

** Ignoring obstruction of body (and/or knees if seated). This obstruction would probably impose a maximum field limit of 90° (or less, seated) directly downward; however, this would not apply at either side, where the potentiality of seeing further downward if the body were transparent extends the total area of the visual field markedly.

*** Maximum possible peripheral field (equal to that achieved with maximum eye deviation). This is limited by the anatomy of the structures around the eye (nose, cheeks, brows, etc.). The figures in brackets on the line preceding each occurrence of this note are calculated values, chosen to result in the maximum limit thus indicated.

4/ Limiting angles of the horizontal and vertical visual fields. All data except as noted are from Hall and Greenbaum (reference).

TABLE 3
Solid Angles of Human Visual Fields[8]

Condition of Movement Permitted	Type of Field	Solid Angle of Total Field Monocular Angle (Sterads)	Monocular (% of 4π) = (% of sphere)	Binocular Angle (Sterads)	Binocular (% of 4π) = (% of sphere)	Unobstructed Solid Angle Seated* Monocular Angle (Sterads)	Monocular (% of 4π) = (% of sphere)	Binocular Angle (Sterads)	Binocular (% of 4π) = (% of sphere)
(a) Head and eyes: moderate movements	Range of fixation	2.40	(19.1%)	2.40	(19.1%)	2.40	(19.1%)	2.40	(19.1%)
	Total peripheral field	9.48	(75.4%)	7.70	(61.3%)	8.88	(70.7%)	7.10	(56.5%)
(b) Head fixed, Eyes fixed (central)	Total peripheral field	4.38	(34.9%)	2.97	(23.6%)	4.25	(33.8%)	2.84	(23.6%)
(c) Head fixed, Eyes maximum deviation	Range of fixation	3.58	(28.5%)	2.75	(21.9%)	3.27	(26.0%)	2.44	(19.4%)
	Total peripheral field	7.48	(59.5%)	3.77	(30.0%)	7.26	(57.7%)	3.55	(28.2%)
(d) Head maximum movement, Eyes fixed (central with respect to head)	Range of fixation	4.74	(38.0%)	4.74	(38.0%)	4.44	(35.3%)	4.44	(35.3%)
	Total peripheral field	11.69	(93.0%)	10.75	(85.6%)	10.88	(86.5%)	9.94	(79.0%)
(e) Head and eyes: both maximum movement	Range of fixation	11.26	(89.6%)	10.54	(83.9%)	10.45	(83.2%)	9.73	(77.4%)
	Total peripheral field	12.28	(97.7%)	11.21	(89.2%)	11.43	(90.9%)	10.36	(82.4%)

Table 3.- The solid angles intercepted by the fields of human vision, calculated from the field limits of Table 1.

The "solid angle of the total field" (as tabulated) includes any visible areas of the body (but not the head). That is, the "external" field visible beyond the body is less than this "total field" value by whatever solid angle is obstructed by the position of the body.

The "unobstructed solid angle" has been corrected for the obstruction of the body when seated. From the "total field" value was subtracted the solid angle intercepted (from the eye-point) by a region extending from hip to hip sideways, and from the knees to the downward limit of the vertical field (when this extends past the knees).

For a standing position, the "unobstructed field" would be intermediate between the values given.

* Anthropometric data from Randall et al[1] were used to find the body angles from which the body obstruction corrections were calculated.

head and eye movements are preferred to more extreme deviations. Conditions permitting gross body movement have not been considered because they result in a demonstrable reduction in the ratio of productive work to energy expenditure—i.e., operational efficiency. Since we are dealing with a reference condition that is selected by preference and an area that probably exceeds practical design limitations, we may use average values.

Inspection of Table 2 shows that, under the conditions of moderate head and eye movement, the total area that can be scanned is: (a) 155° horizontally both to the right and left of the mid-central anatomical position of head and eyes, (b) 91° upward, and (c) 112° downward. This total area is all potentially useful in detecting and avoiding collision with outside objects. At the periphery of the area, there are regions that can be seen by only one eye—i.e., the right eye but not the left, or vice versa. The peripheral field is important for the operation of airplanes and other vehicles, even though vision is not acute, because the vague image signals the presence of another object. The visual consequence of this type of perception is to turn and fix the gaze on the object for further details concerning its nature and location. The more central region of the total area includes a form field that can be seen with both eyes simultaneously. This is: (a) 105° to the right and to the left, (b) 91° upward, and (c) 112° downward.

This binocular form field, in turn, includes a relatively large area that serves for acute vision for precise visual tasks (fixation) with both eyes at once. On the basis of head and eye movements that have been assumed, this is: (a) 60° horizontally to either side and (b) 45° vertically, up or down. These values are pertinent in considering visibility both outside and inside the cockpit.

Design and Evaluation of Structure in Relation to Human Capacity for Seeing

Quantitative description of man's capabilities for viewing an expanse provides a sound basis for designing and for evaluating cockpit visibility. It can provide a direct measure of the success of the design. This approach appears preferable to the type of comparative evaluation which is commonly used today—i.e., manufacturer A's product is more or less satisfactory than manufacturer B's product; such comparison gives little clue to how far man's visual capabilities can be used in either airplane.

In employing criteria for visibility rating, it would be necessary first to require that certain critical areas be free from obstruction and provide an adequate quality of vision. These highly important areas that have been considered by McFarland[5] and more recently in the extensive studies of Pigman and Edwards[6] are determined by operational requirements. In 1950, the latter investigators presented summary charts, based upon the judgments of a large series of experienced pilots, to show estimates of visual operational requirements at different azimuth angles. According to their results:

(a) No obstructions should be present within 30° to the right and left of the forward (zero position); unobstructed areas within 50°–60° boundaries to right and left are desirable.

(b) Vertically unobstructed vision should be provided upward 13° and downward 15° from forward eye level.

(c) Only minor obstruction—e.g., thin posts less than 1 $^1/_2$ in. wide—within 110° azimuth of the forward direction.

Provided that these (or other) conditions for clear, unobstructed vision are satisfied, the adequacy of the windshield-window area could be rated by the ratio:

$$W = \frac{\text{Total solid angle of windshield-window area}}{\text{Solid angle of human visual field}}$$

The total field that is viewed with moderate eye and head movements is a solid angle of 9.48 steradians (75.4 per cent of the total solid angle of a sphere). This solid angle is exceeded by that of the visual field under two other conditions of movement—i.e., extreme movement of the head with eyes fixed in central position in the orbit (11.69 steradians) and with extreme movements of both head and eye (12.28 steradians). The values given for solid angle under various conditions have been calculated by Sutro, biophysicist at the Civil Aviation Medical Research Laboratory at Oklahoma City, on the basis of a new theoretical approach developed during the course of his visibility studies.*

The mathematical difficulty in calculation of visual field in terms of solid angle results from differences between the limiting angles subtended along different meridians and from a lack of complete data for all meridians. Accurate data are available for only four meridians—i.e., right, left, up, and down. If there were data on field angles at 15° or even 30° intervals, a numerical integration could be carried out. Previous calculations have assumed an average (constant) radius at each meridian. Sutro has arrived at a closer approximation by observing that the field must have an area intermediate between the areas of two concentric circles with radii equal to largest and smallest angular field limits that are assumed to be on the horizontal and the vertical axes. The geometric mean between the areas of these circumscribed and inscribed circles, which is equal to the area of an ellipse passing through the axial limits, is taken as the area of the field.[8]

Values for Visibility Ratings

Sutro has calculated the ratio W on the basis of data of Hall and Greenbaum for man and the data of Pigman and Edwards for several transport aircraft (Table 4). He offers some estimates of the correction for body obstruction for a pilot in the seated position. The highest rating score shows that the solid angle of

* This project is being conducted under the auspices of the Commission on Accidental Trauma of the Armed Forces Epidemiological Board, with support by the Office of the Surgeon General of the Department of the Army.

TABLE 4

Ratings (W) of Windshield Area in Some Transport Airplanes

	Douglas DC-3	Douglas DC-4	Douglas DC-6	Lockheed Constellation	Convair 240	Martin 2-0-2
* Solid angle of total windshield area (steradians)	2.041	1.478	1.310	1.632	1.972	1.328
* Percentage of total solid angle in sphere (12.57 steradians)	16.25	11.76	10.4	12.4	15.7	10.6
Percentage of solid angle in human visual field † (W)	21.5	15.6	13.8	17.2	20.8	14.0

* Data directly from Pigman and Edwards.[6]

† Field of human vision taken for this calculation as the uncorrected peripheral monocular field for moderate movement of head and eyes (see Table 3), which covers *9.48 steradians* solid angle (75.4 per cent of sphere). This is very nearly equal to the monocular *fixation* field of 9.73 steradians solid angle (77.4 per cent of sphere) found from the range of fixation when maximum head and eye movements are permitted (Table 3), after correction for body obstruction.

total windshield-window area represents only 21.5 per cent of the solid angle in the human visual field (9.48 steradians, uncorrected for visual obstruction offered by pilot's body).

The question of what score would constitute excellent visibility cannot be settled at this time. Six types of air transport aircraft now operating successfully have total area scores of 13.8 to 21.5. Subjective estimates of excellence of visibility are necessarily based upon comparison with other aircraft and perhaps, as pointed out by Pigman and Edwards, by characteristics of the airplane to which the pilot is accustomed. That some improvement could be achieved, by providing for fuller utilization of man's capacity for seeing, or by improvement of vision through the critical areas, or by both measures, is indicated by the relatively high incidence of near misses in flight resulting from not seeing approaching airplanes. Theoretically at least, some improvement would be expected by provisions to permit viewing up to the limit of human capabilities. Transparent areas for visibility, when extended to limits of practicability, could be supplemented by mirrors or viewing spheres as suggested in the Pigman and Edwards report.

LOCATION OF CONTROLS

Arm-Reach Measurements

Dynamic arm-reach measurements serve as a basis for the location of manual cockpit controls. Arrangements of controls should permit the pilot to operate his aircraft without disturbing his normal sitting posture. This view is supported by several well-established physiological observations:

(1) The efficiency of operation of a control is reduced progressively as the movements of the fingers and hands are extended to movements of the forearm, arm, shoulder, and trunk, since increasingly greater amounts of energy are used as the mass of the body parts involved in the operation is increased.

(2) Time for operation increases as the distance between the pilot and the control is increased. The absolute time for moving the hand and arm is not great, but it has been shown to increase from 30 to 80 per cent as the object is moved from 8 to 24 in. away from the subject.[10] Greater time increases result where distances require movement of the shoulder and trunk.

(3) The precision of movement is decreased when it becomes necessary to support an extended arm. Further, the precision of movement is affected more adversely by accelerated forces when the arm is extended. Leaning forward—i.e., bending the trunk—involves gross movement and strong action that affect precision to an even greater degree.

(4) "Off balance" positions, with the pilot's head buried in the cockpit, interfere with the pilot's sense of position and movement—i.e., his orientation in space. Muscle adjustments used to retain balance in awkward positions must be discounted or overcome in applying the correct pressure for operating a control. Outside vision is, of course, reduced or lost during extreme body movement.

These observations should not be interpreted as implying that a pilot should maintain his operating position without body movement, since this would be most unwise for a number of sound physiological reasons. They do mean, however, that operational efficiency is significantly reduced if the pilot is required to make excessive body movements as a necessary condition for the operation of his airplane.

Data on distances that will be satisfactory for a large percentage of any pilot population have been presented in an earlier report but are included here for use in combination with other descriptions (Table 5).[11] The exact percentage of the general pilot population for which these results are suitable will vary from those

TABLE 5*

Reach Measurements: The Maximum Distances at Which a Large Percentage of a General Pilot Population† Will Be Able To Reach and Operate Manual Controls Located at Various Points in the Working Area[2]

Level (Inches) Above Seat Reference Point	Angle (Degrees) 0	R15	R45	R75
46	11.6	13.7	15.0	17.0
40	18.9	20.5	22.4	24.1
34	22.9	24.9	26.6	28.0
28	25.5	27.1	29.1	30.1
22	26.7	28.2	30.3	31.4
16	26.6	28.0	29.7	31.6
10	25.3	27.0	29.3	30.4
4	22.6	24.2	26.4	27.9
−2	17.5	19.7	21.8	22.8

* Distances for right arm reach are measured from the vertical line through the reference point with the subject's shoulders touching the back cushion; seat back 13° from the vertical. The reference point is taken as the upper level of the seat cushion at its line of intersection with the small lower cushions of the back pad (Warren McArthur seat). R15° stands for 15° to right. Reach for left arm can be outlined by using above measurements at corresponding points to the left of 0°.

† These distances were suitable for 97.7 per cent of the 139 subjects studied at each position, and suitable for 93 per cent of the group at all positions.

shown for the population that was studied. However, it is expected that only a few of the pilots will have arm and other body dimensions that will prevent their reaching the controls at the distances specified.

On first consideration, it might appear reasonable to attempt to provide for differences in reach through horizontal seat adjustment, but further analysis indicates that this will not result in a satisfactory solution. The distances that can be reached depend upon a number of body measurements including arm length, sitting height, breadth of shoulders, chest depth, and undoubtedly others. These dimensions do not bear a sufficiently constant relation to one another or to body measurements upon which other arrangements must be based to enable solution of the problem by longitudinal seat adjustment. This situation is well illustrated by the ranges of various body measurements in pilots of the same stature. In a group of Air Force cadets, all 68.5 to 69.5 in. tall, arm length (anterior arm reach) varied from 31 to 39 in. and sitting height from 34 to 39 in. No practical method has been found for predicting the distances that can be reached to the front, side, up, and down from combinations of body dimensions. It has been necessary to measure the reach distances directly. Providing satisfactory seat adjustment is further complicated by leg length. In the same group of Air Force pilots referred to above, one measure of leg length (patella height) varied from approximately 20 to 24 in. and an index for length of thigh (buttock-knee) from 22 to 26 in. Even wider variations in body measurements are encountered when men of greater and lesser stature than 69 in. are considered.

These characteristics in man have resulted in the current practice of providing multiple adjustments for seats and rudder-brake pedals to provide for variations in horizontal line-of-vision, leg reach, and arm reach. In spite of these adjustments, some manual controls are still too far away in most, if not in all, transport aircraft. Pilots must still make excessive body movements and bury their heads in the cockpit in order to reach and operate manual controls. I submit the suggestion that the manual controls and the windshield be brought back closer to the pilot and that the controls be located within the distances from this position specified as being satisfactory for a large percentage of the pilot population. This would have the additional advantage of placing the pilot closer to the windshield, reducing the restrictions to outside visibility imposed by the boundaries and opaque structure of the windshield. Differences in line-of-vision between individuals and for the same individual in different phases of flight would still require vertical seat adjustment. Differences in leg length could be provided for by more effective arrangements allowing for the adjustment of rudder-brake pedals. This approach would require some deviation from conventional thinking and conventional design, but it provides a direction for developments that would increase the operational efficiency of the pilot.

Positioning of Foot Controls

Considerable data on the location of foot pedals have been developed by the Air Force investigators at Wright Field.[7] Satisfactory locations are given in relation to various seat heights and heel to line-of-vision dimensions. Further, the results of three independent studies are in close agreement in specifying the thigh-leg comfort angle for rudder-brake pedal operation. Measurements at Randolph Field showed that when experienced heavy-bomber pilots were allowed free choice of arrangements they adjusted the seat and rudder pedals so that the angle of the knee, as measured along the upper surface of the thigh and the forward surface of the leg, was 111° ± 5°.[12] Measurement of the knee angles shown in diagrams appearing in a report from Wright Field shows values of approximately 111°; since the report does not make reference to the original Randolph Field paper, it is presumed that this represents substantiating data from another study.[13] Another independent investigation by Swearingen, when he was at the Naval Medical Research Institute, adds further support for the preferred knee angle.[14] Subjects were tested at three seat heights and three pedal adjustments that resulted in knee angles from 56° to 135°. The angle of choice varied between 99° and 122°, with an average of 109.3°. Individual comfort angles and the horizontal and vertical distances of the pedals in neutral position from the seat reference point are given for nine subjects (Table 6). The seat reference point is the same as was used for arm-reach measurements.

Since two of the studies[12, 14] were made without consideration of manual controls, the data are applicable for positioning of foot pedals. Current standards for range of rudder-pedal adjustment should, however, be reviewed if new designs are based upon the forward positioning of the pilot seat for improved conditions of arm reach and of vision.

Stable Platform for Operations

A stable platform for operations is a primary requisite for efficient pilot performance and for safety. Functional arrangements for pilot seating should provide such a platform. It should have the necessary structural strength and should ensure adequate support and stability for the pilot's body during normal operation and during the critical period of an emergency situation.

Body Weight

Pilot body weights and decelerative forces encountered in flight and during a crash determine strength requirements for seats, seat belts, shoulder harness, and their attachments. In view of our lack of knowledge of the statistical distribution of decelerations in aircraft crashes, precise statement of body weight may appear to be an unnecessary refinement. However, accurate knowledge of body weights should aid the engineer by, first, providing a predetermined

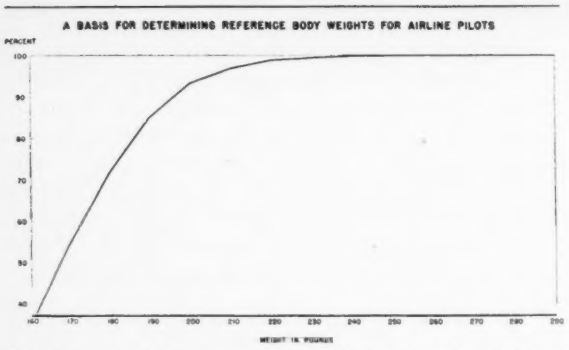

FIG. 2a. Cumulative percentage distribution of nude weights of 7,322 male, commercial air-line pilots examined in 1948.

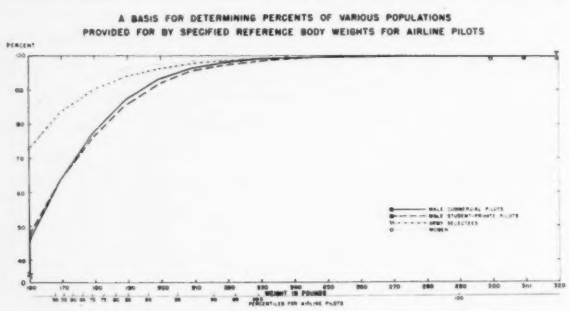

FIG. 2b. Cumulative percentage distribution of four series of nude body weights with scale showing percentiles for air-line pilots.

degree of safety, and, second, reducing an unnecessarily great "blanket" provision to be included in his added percentage safety factor because of uncertainty of the load imposed by the human body.

Of all the quantitative descriptions of man required by the design engineer, body weights would appear to be the simplest and most readily available. However, values determined by medical measurement are not directly applicable, since they are based on nude body weight. Unfortunately, they are used (except in certain military specifications) without considering the 10 lbs. more or less which are added by men's clothing and pocket contents. Further, it has been customary to employ average weight as a reference value. The results of a Civil Aeronautics Administration study of over 7,300 air-line pilots show that the average nude body weight is 167 lbs. (Fig. 2a). A reference weight of 214 lbs. would be satisfactory for 95 per cent of air-line pilots—i.e., this weight would be exceeded by only 365 of the men in this group. The 214-lb. cutoff would also provide for approximately 97 per cent of commercial and student and private pilots (Fig. 2b).

Body Stability

Satisfactory seating arrangements should enable a pilot to fly his airplane without diverting attention or muscular energy to maintain upright posture even under conditions of severe turbulence. Lack of stability not only prejudices control of the aircraft but contributes to distracting discomfort and muscular fatigue during prolonged flight.

It would appear desirable to reduce, insofar as possible, the pilot's dependence on primary flight controls for body support. Protection against forward displacement of the body is provided by the rudder-brake pedals under most flight conditions. This support, however, requires contraction of the muscles of the thigh and leg to fix the hips and contraction of the back and abdominal muscles to fix the trunk at the hip joints. Lateral stability also depends primarily upon the force exerted against the rudder pedals and, to a lesser degree, upon the wheel and the frictional resistance between seat surface and the body. The effect of the wheel component can be judged roughly from the reduced lateral stability in airplanes operated with a stick. Under present arrangements, little can be done to counteract upward movement except to fasten the seat belt and to try to maintain balance when contact with the seat is lost. Many pilots have come to accept this situation as a necessary condition of operation so familiar to them that they are not consciously aware of it.

There are few data at this time on the forces that result in significant displacement of the body from a seated position. Some experimental investigations that have been carried out by Swearingen, however, illustrate the extent of body movement that may result when extremely moderate forces are applied to men in a sitting position restrained only by a seat belt. In these tests the subject grasped a bar attached by means of a cable to a 150-lb. weight; his feet rested upon a pad on a waxed surface to prevent him from bracing himself. A release mechanism was tripped, and the fall of the weight jerked the subject forward from his seated position and at the same time operated the shutter of a camera that photographed the forward arc of the head (Fig. 3). The forces involved, which represent only a small fraction of those which act in airplane crashes, resulted in forward movement of the head for a distance that exceeded the subject's sitting height. The results of these trials on 100 subjects show that, where adequate support is not provided, the minimum forward head clearance requirement cannot be less than 42 in.; where higher forces are involved, it is probably in excess of this value (Table 7). Other studies, being supported by the Office of Naval Research, are under way at the Civil Aviation Medical Research Laboratories which should yield more information on the relation between force and body displacement. Until further data are available, it is difficult to formulate the problem and determine the degree of protection that is desirable or, in some instances, necessary. There is, however, a practical method of greatly improving stability. This is the use of the shoulder harness. The benefit of the additional support can easily be demonstrated by comparing the effects of suddenly pushing down the nose of an airplane when wearing a shoulder harness and when using only a seat belt. An even more striking comparison is

TABLE 6

Relation of the Comfort Knee Angle to the Pedal Distance (in Inches) As Measured from the Seat Reference Point (Measurements Represent Values and Averages for the Three Subjects in Each Group)[14]

Body Type	Leg Length (inches) T1	T2	T3	Seat Height (inches)	Distance to Pedal From Reference Point (inches)* Horizontal T1	T2	T3	Av.	Vertical below R.P.	Angle of knees (degrees) T1	T2	T3	Av.
Tall	45.7	44.0	44.5	15	37.5	35.5	38.5	36.8	10	109	110	122	114
				12.5	38.3	36.5	37.5	37.4	7	108	108	112	109
				10.5	39.3	35.3	36.7	37.0	5	114	104	109	109
	M1	M2	M3		M1	M2	M3			M1	M2	M3	
Medium	44.0	42.7	42.0	15	35.3	34.5	35.3	35.0	9	109	110	114	111
				12.5	38.0	33.3	35.0	35.4	7	110	111	105	109
				10.5	36.7	34.7	35.2	35.6	5	105	112	103	107
	S1	S2	S3		S1	S2	S3			S1	S2	S3	
Short	38.7	38.5	42.1	15	35.7	30.3	31.5	32.5	8	110	113	104	109
				12.5	34.3	32.0	35.0	33.7	5	106	114	102	107
				10.5	32.7	34.0	34.5	33.8	3	99	117	110	109

* Reference point is the same as that described for arm reach measurements (Table 5). N = 9; the percentile points for subjects, when placed in height distribution for series of 2960 AAF cadets[7], are 91.9, 91.9, 76.4, 62.1, 57.9, 21.5, 17.0, 15.9, and 15.9. For purposes of comparison, this group of nine men has been split into three equal groups by height -- tall, medium, and short.

afforded by flying through a region of severe turbulence with and without a harness. Adjustable shoulder wedges provide another possible arrangement for increasing stability in flight.

Further, the protection against fatal or serious head injury which is afforded by a shoulder harness during a crash is well known. Thus, the use of a shoulder harness provides a method of increasing body stability under normal and emergency conditions. It has been shown by experimental studies that when wearing current types of shoulder harness the pilot can still carry out the extensive body movements required to reach and operate the controls of current transport aircraft.[15]

Decompression, resulting from a structural failure, represents an emergency situation that may cause a man to be literally lifted from his seat if he is not restrained. Major displacement of the body results even when a protective harness is worn. As we enter a period of high-altitude commercial flights, every precaution should be taken for pilot protection because, even though the probability of the occurrence is extremely slight, the consequences of such an accident would be far too serious to accept as a normal operational risk. There is no assurance that the shoulder harness provides protection for a pilot under all types and locations of failure, but it would materially reduce the chance of his being knocked about and injured.

SUMMARY

In summarizing, I should like to repeat that measurements of man are essential for making airplanes to fit man. I urge that you give critical attention to the pertinency of quantitative biological data for application to operational conditions and that, once having

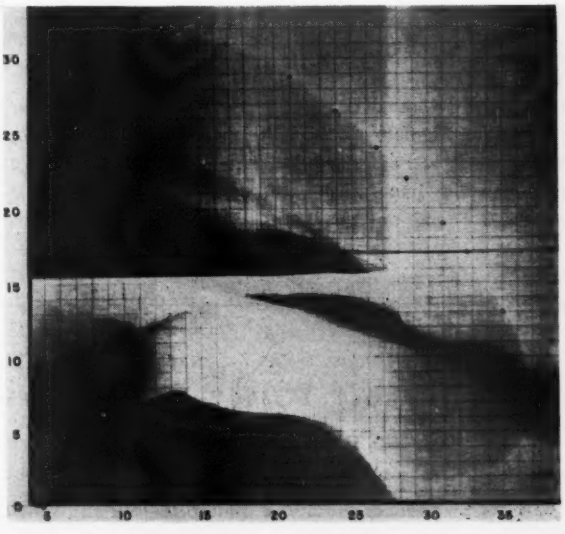

FIG. 3. Shadowgraph of subject 88A in decelerative test (f4.5, 1/2 sec.). Vertical distance in inches. Horizontal distance from reference point in inches.

TABLE 7
Mean Distances for Forward Head Movement of Seated Subjects Restrained by Lap Safety Belt[16]

	3-In. Belt, $N = 100$			2-In. Belt, $N = 96$		
Test Condition	$\bar{x}$, In.	$\pm s_{\bar{x}}$, In.	$\pm s$, In.	$\bar{x}$, In.	$\pm s_{\bar{x}}$, In.	$\pm s$, In.
* Natural	31.04	0.16	1.632	32.09	0.16	1.592
Static-suspended weight	34.00	0.15	1.509	34.11	0.16	1.600
Dynamic-drop weight	37.05	0.17	1.712	36.66	0.20	2.012

* Natural refers to maximum forward position of head which can be voluntarily assumed without action of suspended or drop weights.

found the proper data, you select values that will serve satisfactorily a large majority of the pilots. I suggest that in developing functional design you apply the same criterion of efficiency which is used for power plants—the ratio of useful work that can be accomplished to the energy cost. If you can reduce the burden that is imposed by unsatisfactory arrangements, the pilot will be better able to deal with the ever increasing complexity of modern aircraft and to operate more efficiently under normal and emergency conditions.

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The Air War in Korea

(*Continued from page 31*)

World War II. On the basis of what they have already disclosed in Korea and of what we know about their progress in the field of atomic energy, we must recognize the fact that the air supremacy upon which we have relied in the past is now being faced with a serious challenge. This challenge can be met only by more serious efforts than any this country has previously contemplated or planned. Whatever the outcome of the negotiations at Panmunjom, we must not relax our efforts to build our air strength."

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THE PRESSURE-JET HELICOPTER
Performance Data and Operating Experience

IGOR B. BENSEN*
The Kaman Aircraft Corporation

ABSTRACT

The paper presents the results of an extensive evaluation study conducted on a pressure-jet helicopter, with particular emphasis on the thermodynamics of its power cycle. Operational experience, mechanical problems, and overall performance of this type of helicopter jet-propulsion power plant are presented and discussed.

A captured German jet helicopter was subjected to a series of rigorous tests and measurements aimed at ascertaining the design parameters employed in it, their interrelations and the relative importance of each parameter on the efficiency of the integrated rotor-power-plant combination. Part of the intent of the evaluation was also to verify the existing theoretical methods for predicting performance of this type of helicopter prime mover.

The measurements showed that the hovering performance of the helicopter was marginal and generally below the standards established in the helicopter industry, even at the time of its construction. The theoretical method with some corrections was substantially confirmed by the measurements of critical thermodynamic elements.

On the basis of data obtained, however, the pressure-jet power cycle, when carefully designed and executed, shows great promise as the most efficient jet cycle proposed to date. It has the further advantages of low installed power train weight, compared to standard shaft drive, and an unusually large power reserve. Lifting capacity of pressure-jet rotors was also found to be insensitive to variations of tip speed; this permits rotor operation always at optimum lift conditions.

(1) INTRODUCTION

FOR SOME TIME NOW the searching eyes of rotary-wing engineers have been turned toward torqueless propulsion means for helicopter rotors. The first truly pioneering effort, dating back to 1943, was made by F. von Doblhoff, in Austria, who successfully built and flew several full-size helicopters with rotors driven by jet reaction. The propulsion method used in the Doblhoff machines was the so-called "central-pressure-jet" system, which employed a centrally located power plant generating compressed air; this air was then mixed with fuel, fed through hollow rotor blades, burned, and exhausted tangentially at the blade tips. The last Doblhoff machine, NR-4, designated also as WN-342, was captured at the end of World War II and brought to this country for detailed evaluation studies.

The evaluation tests and data analyses were carried out by the General Engineering and Consulting Laboratory of the General Electric Company, under the auspices of the T-2 Intelligence Section, Air Materiel Command, U.S. Air Force, in connection with a similar jet power plant under development for the XH-17 cargo helicopter.

Presented at the Session on Rotating Wing Aircraft, Twentieth Annual Meeting, I.A.S., New York, January 28–31, February 1, 1952.

* Chief of Research. Views and opinions expressed in this paper are those of the author and do not represent the policies of Kaman Aircraft Corporation or the General Electric Company.

(2) RESULTS

Results of this investigation indicated that, based on contemporary standards, the WN-342 helicopter had marginal performance; with the piston engine rated at 135 shaft horsepower, only 96 hp. was delivered to the rotor with a specific fuel consumption of 3.13 for the tip burners and 0.62 for the engine, or a total of 3.75 lbs. per hp.-hr. for the whole power plant, based on the rotor horsepower. With this power the rotor lifted a gross weight of 1,380 lbs. At maximum power, useful load was 33 per cent of the gross weight at a power loading of 14.4 lbs. per rotor horsepower, or 10.2 lbs. per shaft horsepower. All above figures applied only to hovering in the ground effect and would be reduced considerably in a fully operational helicopter.

This poor showing of the jet reaction drive in the Doblhoff machine, however, was not inherent in the power cycle itself. It could be traced to a number of engineering compromises, obviously forced upon the designers by war handicaps, which introduced disproportionately large losses throughout the cycle. They will be further qualified in the discussion.

It will be seen from the summary curve in Fig. 15 that the lift of a pressure-jet-powered rotor was found to be relatively insensitive to tip speeds. In this particular case, 40 per cent variation in rotor speed resulted in rotor lift variation of only 5 per cent. Rotor speed, therefore, can be varied by the pilot over a wide range to maintain optimum lift conditions.

Another significant finding was that dynamic jet thrust was found to be substantially equal to static jet thrust at all tip speeds, as can be seen from Figs. 8 and 14. This will be further qualified in Section (6).

On the basis of data obtained during the evaluation study, supported by the theoretical analysis, pressure-jet cycle emerges as an extremely attractive power plant for helicopters. When employed in conjunction with an efficient shaft prime mover, such as a piston engine or a shaft turbine, it offers a possibility of highly efficient cruise operation with an unusually large power reserve available for maximum hover and high-speed performance. This is illustrated in Fig. 1. The noteworthy feature in this type of power plant is the relatively small size and weight of the shaft prime mover,

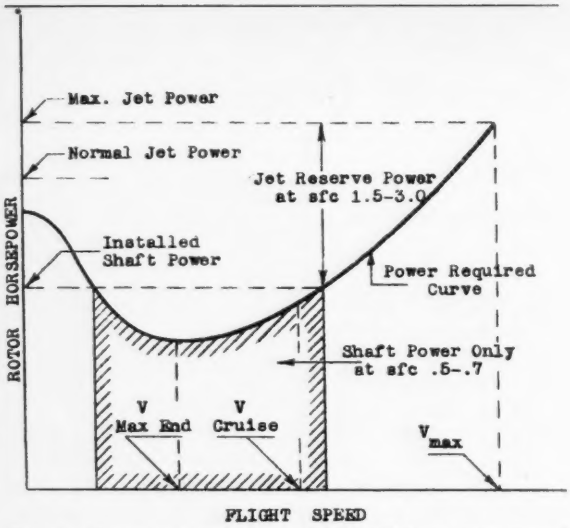

FIG. 1. Power augmentation and high-efficiency operation of pressure-jet cycle.

since it need not provide full hovering power, yet is adequate as the sole source of power for all normal forward flight operations. The less efficient jet drive may then be regarded as a means of power augmentation, similar to afterburning in fixed-wing aircraft, and would be used relatively infrequently. The amount of power augmentation would depend on the chosen design parameters, but it can readily double the installed shaft horsepower. Multiengine reliability would be a welcome by-product of a good design, since tip burning alone can furnish sufficient power for all normal flight in case of main engine failure.

While the above advantages may seem to be insignificant for helicopters in the 135-hp. class, the added complication of tip burning is well worth considering for helicopters in and beyond the 500-hp. class, especially in those designs where great emphasis is placed on pay load, range, and endurance.

(3) General Description

Comprehensive descriptions of the Doblhoff helicopter were given in references 1, 2, and 3. Reference 1, of which this paper is a brief digest, contains a much more detailed account of the evaluation study and performance data obtained. Space and time limitations will make it necessary to confine the general description of the machine only to those features that have a direct bearing on its performance.

FIG. 2. Doblhoff helicopter.

To avoid the danger of arriving at erroneous conclusions, several important criteria must be kept constantly in mind in analyzing the performance of the Doblhoff helicopter.

First, by original design, the Doblhoff machine was intended to be a *pusher autogiro*. Direct lift feature was to be used only during the take-offs and landings. Since the vertical flight generally consumes only a small portion of the total flight time, a number of unavoidable engineering compromises were apparently made in favor of the craft's primary function—i.e., of the autorotative flight. Its helicopter performance, power-cycle efficiency, specific fuel consumption, life and design of its components, etc., cannot be criticized without the proper allowance for this basic design philosophy.

Second, the craft was built in 1943–1944 when war shortages in Germany did not permit the designers to select or manufacture the components to exact specifications demanded by theoretical considerations. To mention a few: no engine of proper specifications was available, so the existing one was speeded up beyond its maximum r.p.m. rating to match the available gear box; similarly, no compressor of proper rating was available, so an engine supercharger rated at 24,000 r.p.m. was modified to operate at 35,000 r.p.m. There were many more compromises of this sort too numerous to be mentioned. Intelligence reports indicated that total development costs of the WN-342 machine with its three prototypes amounted to an equivalent of $100,000 and work was done under such hardships as being allotted one drum of gasoline per month for all operations.

Fig. 2 shows the craft as it was received in this country. The pusher propeller and its associated controls unfortunately were missing when the machine was delivered.

Autogiro flights were never made by the Doblhoff machine either here or abroad, although test data on transition from hovering to forward flight and back would have been of great scientific interest. The absence of the pusher propeller, clutches, etc., precluded its evaluation in this country.

The propeller-like member seen in the photograph is the thin sheet steel fan, which was provided for directional control by blowing air over the rudder. In passing, it may be remarked that in spite of absorption of 3 to 5 per cent of engine power by the fan, directional control obtained with this scheme was poor and obviously inadequate for hovering in winds above 10 m.p.h.

Physical dimensions and specifications of this helicopter are given in Section (4).

For the benefit of the reader not familiar with the Doblhoff helicopter, we shall recapitulate briefly its power-plant design.

An inverted, air-cooled four-cylinder engine formed the nucleus of the power plant (see Fig. 3). The shaft end, carrying a flywheel and a pusher propeller, was lo-

cated aft of the ship. The accessory end of the shaft carried a 14.8:1 step-up gear box, which drove a small centrifugal compressor located just behind the pilot's seat. There were two exit nozzles in the compressor scroll; the two outlets were connected by two flexible rubber ducts to a common header just beneath the rotor hub. Hence, the compressed air proceeded into a revolving plenum chamber and then entered into three rotor blades. Rotor blades were hollow and served as air ducts between the hub and the tip burners.

Two independent fuel tanks were mounted above the engine: (1) engine tank of 7.0-U.S. gal. capacity, with the flow rate of 11 gals. per hr. and (2) jet tank of 17.0-U.S. gal. capacity, with the flow rate of 54 gals. per hr.

Jet fuel, a low-octane gasoline, was injected into the air stream in vaporized form just downstream of compressor outlets. Engine exhaust heat was used to vaporize the jet fuel in the vaporizer heat exchanger. Air-fuel ratio metering was controlled in liquid phase by an automatically responsive valve measuring compressor outlet pressure.

The combustible mixture of approximately stoichiometric composition, therefore, flowed through the rubber ducts, the plenum chamber, and the blades. Near the blade tips it passed through a group of flame arresters, shown in Fig. 4, and finally into the combustion chambers, where it was burned and turned through 90° to exhaust tangentially into the atmosphere.

It should be pointed out that no blueprints, specifications, or replacement parts of any sort came with the helicopter. In addition, there was a great number of makeshift, damaged, and partially missing components. With all these handicaps, multiplied by the fact that it was built entirely on the metric system, it was indeed a great labor to operate and maintain this machine.

(4) General Specifications

The following specifications applied to the WN-342 helicopter.

(*a*) *Dimensions*

Height	108.5 in.
Width (minus rotor)	99 in.
Length (minus rotor)	239 in.

(*b*) *Weights*

Gross (max.)	1,380 lbs.
Empty	960 lbs.
Useful load	420 lbs.

(*c*) *Rotor*

Blades	3 hollow, metal
Diameter	34.03 ft.
R.p.m. (optimum)	275
Chord	5.87 in.
Solidity	0.027
Airfoil	NACA 23018
Blade duct area	3.0 sq.in.
Chord twist	0° at tip, +6° at root, nonlinear

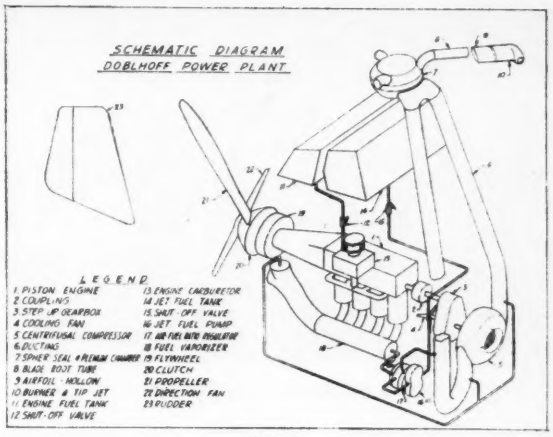

FIG. 3.

Taper	None
Disc area	910 sq.ft.
Blade area (actual)	18.3 sq.ft.
Disc loading	1.52 lbs. per sq.ft.
Blade loading (actual)	75.5 lbs. per sq.ft.
Blade weight (with tip)	46.19 lbs.
Delta-three angle	0°
Jet orifice area	1.92 sq.in.
Tip speed	490 ft. per sec.

(*d*) *Power Plant*

Engine: Argus Model as 8B, Series 1. 4 cylinder inline, inverted, air-cooled

Rating	135 hp. at 2,200 r.p.m., 5 min.
	125 hp. at 2,150 r.p.m., 30 min.
	115 hp. at 2,090 r.p.m., cruising
Fuel consumption hovering	65 lbs. per hr.
Fuel	90-octane aviation gasoline
Capacity	7.0 U.S. gals.

Compressor: Argus Model 411

Compression ratio	2.04
R.p.m.	35,000
Mass flow (static)	1.21 lbs. per sec.

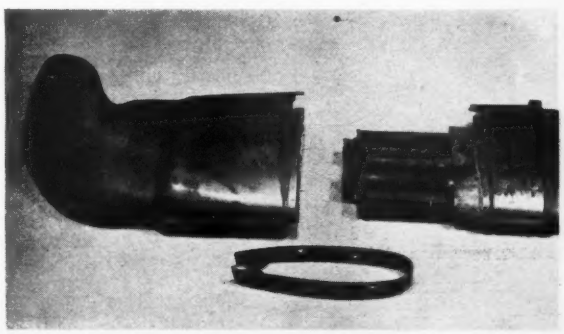

FIG. 4. Blade tip and burner.

FIG. 5. Rotor calibration on mechanical dynamometer.

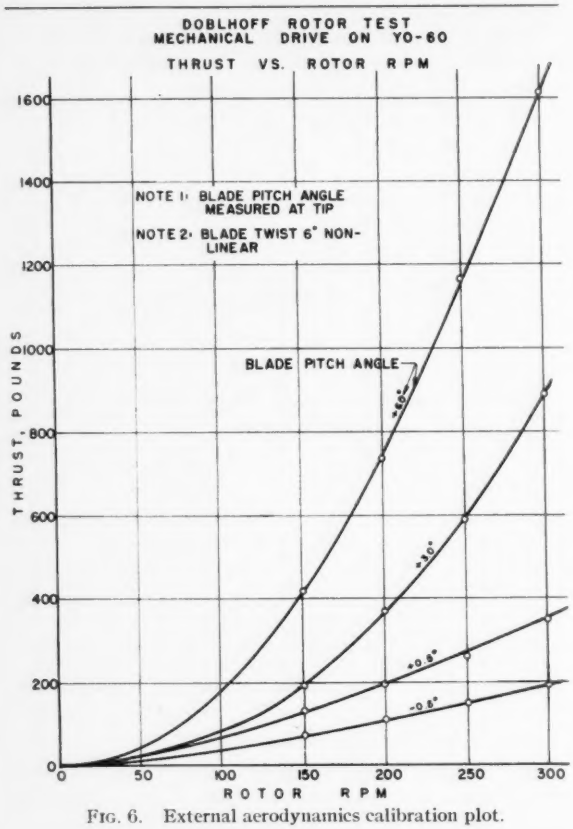

FIG. 6. External aerodynamics calibration plot.

FIG. 7. Static measurements of jet thrust.

Number of discharge ducts	2
Discharge temperature	270°F.
Reaction Jets:	
Fuel	67-octane "white" gasoline
Fuel consumption hovering	326 lbs. per hr.
Capacity	17.0 U.S. gals.
Discharge temperature	3,900°F.
Total nozzle area	5.77 sq.in.
Total fuel weight	144 lbs.

(5) TEST PROGRAM

The Doblhoff helicopter was subjected to a whole array of tests covering thermodynamics, aerodynamics, stress analysis, vibration, transient conditions, resonance, control analysis, x-ray, magnaflux, etc. Most of these were so intimately interconnected it would be too laborious to separate them into independent sections. To make the presentation of this material coherent and yet mention the results of many unrelated tests, it seems more desirable to discuss each component of the helicopter in some logical sequence, stating the findings of each of the analyses. This will be done in Section (6) under the heading of Evaluation of Components.

There were seven groups of tests of major importance. They were as follows.

(1) Run-up of the machine as received, familiarization with its operation. Mr. Doblhoff himself spent two weeks at the laboratory instructing the mechanics in its maintenance and acquainting the engineers with its background.

(2) Overspeed and flutter tests. Rotor was shaft driven by an electrical dynamometer in an enclosed pit.

(3) External aerodynamics calibration test, measurements of lift vs. horsepower input. Rotor was shaft driven by an engine dynamometer (a converted autogiro) through a sensitive torquemeter (see Figs. 5 and 6).

(4) Internal thermodynamics test on the helicopter, rotor stationary. Airflow and pressure measurements, jet thrust, fuel consumption, burners water-cooled (see Figs. 7 and 8).

(5) Vibration, flutter, and ground resonance tie-down tests. On the ground only, at full range of rotor speeds.

(6) Compressor calibration measurements (see Figs. 9 and 10).

(7) Overall performance test, rotor self-powered in the ground effect. Lift vs. r.p.m., pitch and power settings; ship tied to scales (see Figs. 11 and 12).

(6) EVALUATION OF COMPONENTS—POWER PLANT

(a) *Engine*

No brake dynamometer nor indicator card measurements were taken on the engine. Therefore, its horse-

power rating of 135 hp. was taken on faith from the Argus engine manual and the data furnished by the military intelligence. It will be noted from the specific fuel consumption that this assumed rating cannot be too far out of line.

Whatever was its actual output, the engine was obviously overloaded even under normal hovering power. It could never be run longer than 10–15 min. at a time and usually overheated itself to the point of compression-ignition and refused to stop when ignition was cut off.

Engine cooling was accomplished by an 8-in. diameter three-blade fan of very low solidity turning at supercharger speed, or 35,000 r.p.m. It was placed at the entrance to the scroll surrounding one side of the engine, the air being displaced axially through the fan and out through the cooling fins of the cylinders. In spite of its lightness, this cooling arrangement is not recommended for helicopter practice, for it is poor in efficiency and is vulnerable to damage. About 7 per cent of engine power was consumed by the fan.

(*b*) *Compressor and Air Ducts*

The original rating of the compressor was not known, although, according to intelligence information, it was designed to operate at 24,000 r.p.m. As mentioned previously, in its actual application, with rotor stationary, it delivered 1.21 lbs. of air per second at 2.04:1 compression ratio, while turning at 35,000 r.p.m. Off-design points can be read from the mass flow curve in Fig. 10.

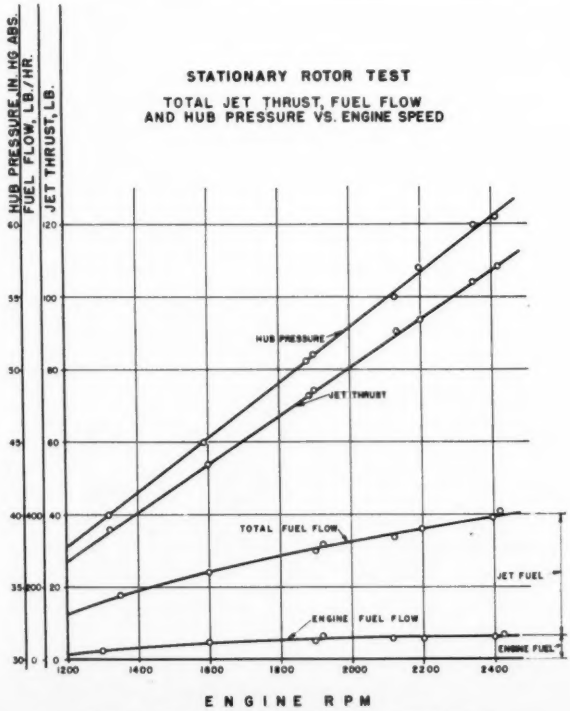

FIG. 8. Plot of static jet thrust measurements.

FIG. 9. Compressor calibration setup.

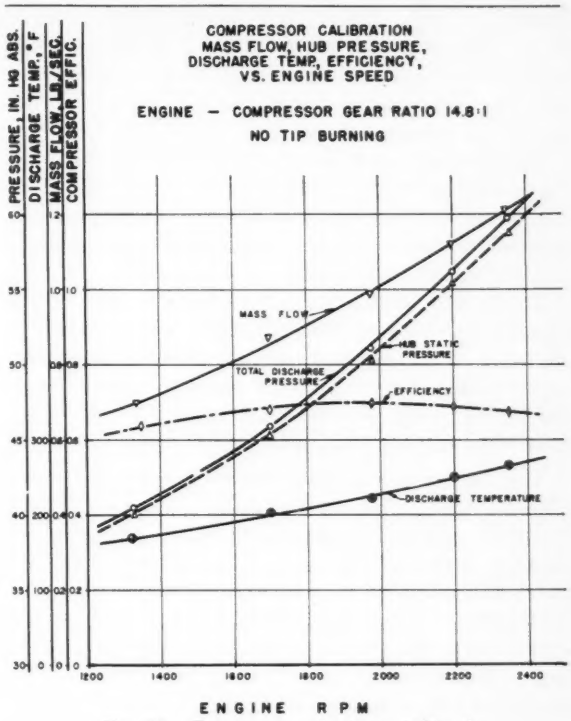

FIG. 10. Compressor output at rated load.

In combination with its gear box, it was a fiercely noisy unit, requiring ear plugs or earphones to be worn by the attending personnel. Sound measurements within 10 ft. of the rotor radius, at full power, indicated a noise level of 109 db. Frequency distribution showed that the impeller and the gears contributed about equally to the total level.

Lubrication and cooling of the transmission were successfully solved by a system of oil jets washing the gears continuously downstream of contact lines. No oil coolers were required. Contrary to the customary helicopter experience, this helicopter had no transmission difficulties whatsoever.

The two air ducts between the compressor and the plenum chamber presented no problems. Needless to say, a single duct would have offered much lower pressure loss, thereby improving the efficiency, but the ac-

tual arrangement was forced upon the designers by the double-outlet design of the compressor. Traverse studies of the airflow showed that velocity gradients in the ducts were extremely distorted, at times to the point of local flow reversal, which was caused by considerable internal skin friction, sharp turns, and steps within the ducts. About 11 per cent of the total pressure was lost between the compressor and blade roots.

(c) *Rotor Hub (See Fig. 16)*

The two outstanding features of Doblhoff's rotor hub were: (1) its spherical bearing pylon support and (2) strap suspension of the rotor blades. Both merit a detailed discussion.

The weight of the ship was supported by the rotor through a single twin-row self-aligning spherical bearing. Thus, the whole rotor could seek a plane of rotation without oscillatory flapping motion of the blades. Flapping (or rocking) hinge function was thus performed by the spherical bearing in the center, while the coning hinge function was in effect accomplished further outboard by the flat steel straps. This resulted in an unusually smooth rotor operation, especially noticeable when large cyclic pitch deflections were applied. The straps supported full centrifugal force of each blade, yet they were weak enough torsionally to allow axial twisting of blades by relatively light control moments. By being placed outside the blades, the straps permitted unobstructed airflow from the plenum chamber into the blades. The overall design yielded a very lightweight hub construction, as well as light stick forces.

The absence of lag hinges, however, was found to be objectionable, for it permitted the generation of undamped blade oscillations in the plane of rotation in forward flight and in ground resonance. Unfortunately also, the peak of ground resonance frequency occurred at 270 rotor r.p.m., which nearly coincided with optimum hovering r.p.m. Shock struts of the landing gear had to be kept in excellent condition to prevent the resonance amplitude from diverging. Tie-down cables were added for safety. However, in spite of all precautions, one blade finally parted during ground resonance condition, and the whole ship was destroyed.

The large spherical seal of about 10 in. in diameter between the stationary and the revolving halves of the plenum chamber was a continuous source of difficulty. The spherical seat machined on its stationary bottom part was scoured and scratched by the interferences caused by uneven thermal and stress deflections. The packing in the upper half could not be maintained tight even though it was of the self-sealing pressure expanding type. The seal could not be lubricated (the contact was between leather and magnesium), because lubricating oils and greases were promptly dissolved by hot fuel vapors and were carried or blown away. During the tests with kerosene as the jet fuel, billowy white clouds of vapor could be seen streaming from the seal. Moreover, kerosene, having a higher boiling point, readily condensed on the walls of the plenum chamber and managed to escape through the seal. As a result, the attending personnel were generously sprinkled with liquid kerosene, and the fire hazard reached serious proportions. Fire hazard, of course, was still present when gasoline was used, even if the escaping gases were invisible.

(d) *Rotor Aerodynamics*

As mentioned previously, rotor blades served the dual purpose of ducting the air to the tips and of producing lift to support the ship. It was not an easy matter to isolate these two functions in order to evaluate them separately. Fortunately, rotor suspension straps were placed far enough apart to allow the rotor to be driven mechanically. The rotor was mounted on top of a vertical dynamometer and whirled with its jet nozzles faired out by streamlined plugs, as can be seen in Fig. 5. Power input was measured accurately by a sensitive electronic torquemeter, while the vertical thrust of the rotor was measured by the scales on which the dynamometer rested. This test calibrated the external aerodynamics of the rotor, which resulted in curves in Fig. 6.

Internal aerodynamic performance was far more difficult to measure. Jet thrust measurements were made with the rotor stationary (shown in Figs. 7 and 8). Although the static data are reliable in accuracy, they do not represent the actual behavior of the power plant under whirling conditions. There are several causes for this difference, some of which are not readily measurable, but their effects must be accounted for. The more important intervening factors are the following:

(1) With a given exit velocity, jet thrust is greater when the rotor is stationary than when rotating.

Theoretically, neglecting the small pressure term across the nozzle, jet thrust is expressed by the equation:

$$T_j = [(W_F + W_A)/g]\,(V_j - V_T)$$

where

T_j = jet thrust
W_F = jet fuel flow
W_A = air weight flow
V_j = jet exit velocity
V_T = tip speed
g = acceleration of gravity, all in compatible units

At the same time, rotor power is given as

$$\text{Rhp} = T_j V_T/550$$

where Rhp = rotor horsepower, if T_j is in pounds and V_T is in feet per second.

From these relations it can be seen at a glance that jet thrust is maximum when tip speed is zero, decreasing gradually as tip speed increases. In the limiting case when tip speed equals jet velocity, jet thrust is reduced to zero. Power output and propulsive efficiency are both zero when the rotor is at a standstill, even though jet thrust is then maximum.

(2) Both air and fuel enter the hub with zero tangential speed; additional energy must be supplied to accelerate this mass to the tangential speed of the tip. This factor is absent when the rotor is stationary.

(3) The above two negative factors are offset by the positive effect of "centrifugal pumping action" of the blades when revolving, which accelerates the mass of air radially and not only increases the mass flow but also increases the compression ratio at the tip. This increases the available energy at the tip and improves the thermal efficiency of the cycle.

(4) Another loss creeps up, however, and that is the additional pressure drop produced by the increased skin friction and larger q factor associated with greater radial velocity of air through the blades.

(5) As the mass flow increases, air-fuel ratio becomes leaner, if fuel flow does not change with rotor r.p.m., which was the case in this helicopter. This may change tip temperature appreciably and invalidate test data, unless properly accounted for.

(6) Last but not least was the centrifugal separation of the fuel from the air, producing a nonhomogeneous mixture at the tip burners. Owing to the large difference in densities of air and fuel vapor, the latter separated in a centrifuge manner and condensed at the trailing edges when the rotor was revolving.

It can be appreciated that this complex accumulation of effects occurring simultaneously along the blade would necessitate an elaborate instrumentation to ascertain the influence of each one cause and effect separately. To simplify the method of measurement, previous external calibration of the rotor on the mechanical dynamometer, obtained in Fig. 6, was used to correlate rotor lift and r.p.m. data with those when the rotor was self-powered.

The latter test, shown in Fig. 11, produced a series of plots such as shown in Fig. 12, corresponding to a number of blade pitch settings. It will be worth noting that at the blade pitch setting shown, the dynamic hub pressures were nearly identical with static hub pressures measured earlier in Fig. 8. Furthermore, hub pressures were found to be nearly independent of rotor r.p.m., as shown in Fig 13.

FIG. 11. Dynamic rotor test.

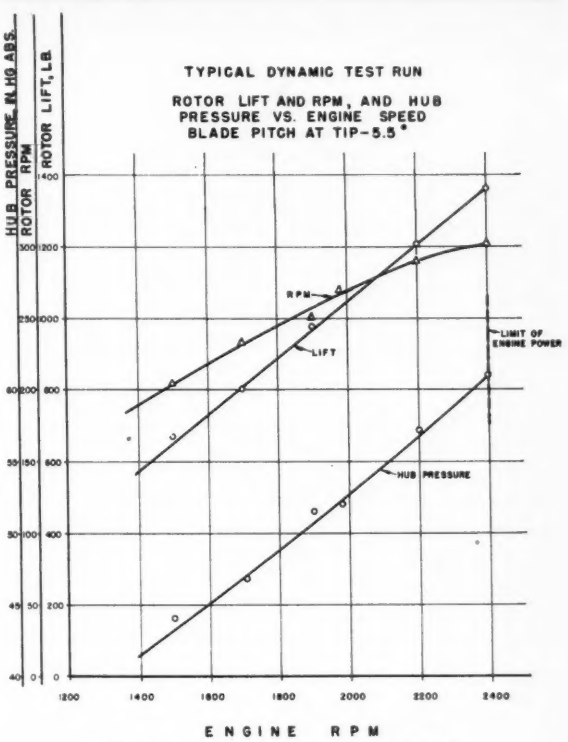

FIG. 12. Typical dynamic test-run data.

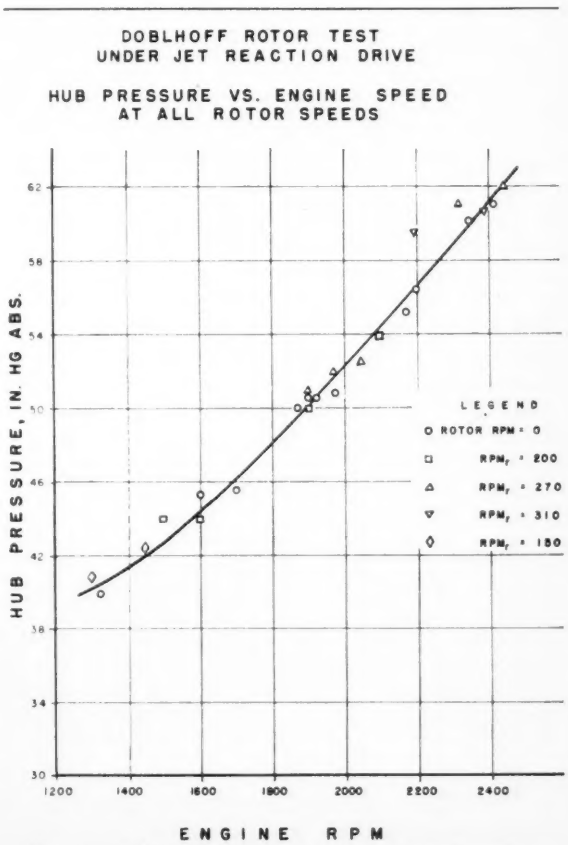

FIG. 13. Effect of rotor and engine r.p.m. on hub pressure.

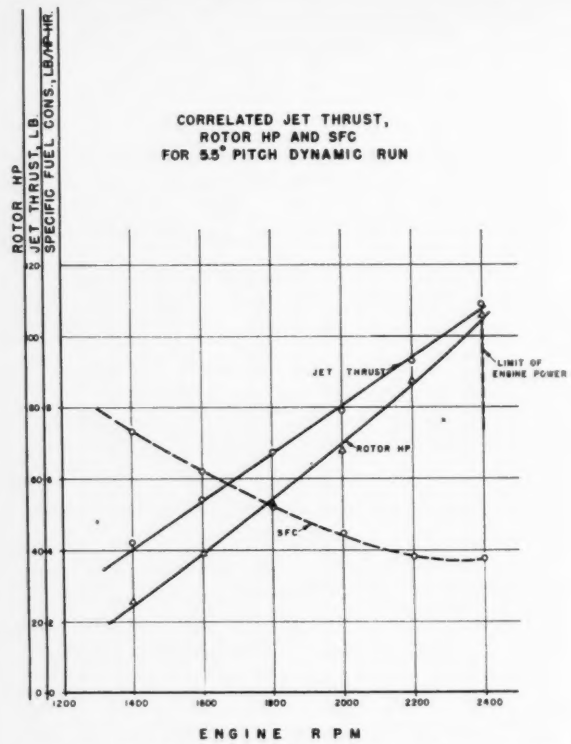

FIG. 14. Correlated dynamic output of the jet power plant.

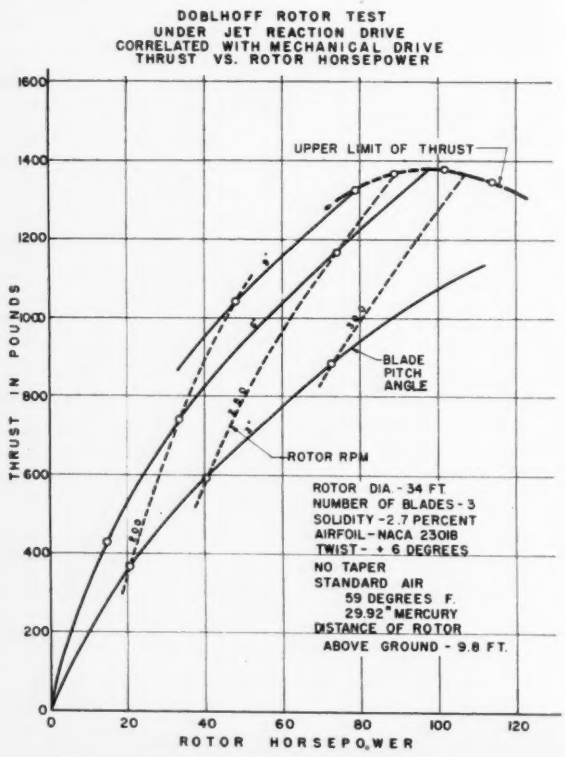

FIG. 15. Summary curve of hovering performance.

With rotor r.p.m., lift, and pitch measured under dynamic conditions, it was then possible to obtain horsepower and jet thrust by correlation with curves in Fig. 6. A sample correlated rotor horsepower and jet thrust are shown in Fig. 14. The specific fuel consumption, based on rotor horsepower, was then computed and drawn on the same plot. It will be seen from the latter curve that partial power fuel consumption of the pressure-jet cycle is high with fixed jet nozzles and nearly constant air-fuel ratio, as executed in the WN-342 machine. It reaches a minimum in the regime of largest power output and is flat in that region.

Accuracy of the correlation was good, as is evidenced by the light scatter of test points. The jet thrust line of Fig. 14 is of particular interest, because, together with Fig. 8, it reveals that at a given pitch setting, dynamic jet thrust exactly equaled the static jet thrust at all rotor and engine speeds. This significant finding indicates that rotation of rotor blades, in addition to raising tip pressure ratio, also caused a substantial increase of air mass flow through the compressor, since pressure rise alone cannot account for the increased jet thrust. The exact equality should be regarded as a coincidence, however, rather than a rule, for airflow variation is a sensitive function of compressor characteristics. In fact, centrifugal pumping and friction losses, which are the two major opposing factors, are unlikely to cancel out exactly in power plants with different basic parameters.

Finally, with all the above data on hand, it was possible to plot the Summary Curve, Fig. 15, which describes rotor performance whether mechanically driven or self-driven.

Of special interest is the Upper Limit of Thrust line, which represents the highest rotor thrust (or lift) attainable with the available engine horsepower. The "full throttle" condition on the piston engine occurred consistently at nearly 2,400 r.p.m. It will be noted that, at full throttle operation, equal lifts were produced with 78 rotor horsepower at 230 r.p.m. and 120 hp. at 330 r.p.m. Maximum lift was only 5 per cent higher than these extremes, occurring at 275 r.p.m. and 96 rotor horsepower. Pressure-jet rotor, therefore, is insensitive to variations of its tip speed (or r.p.m.) in producing a given lift with a given engine power. Jet thrust, however, shows only a slight variation with rotor r.p.m., as mentioned earlier, and thus becomes a more significant criterion than rotor horsepower in determining the lifting performance of a pressure-jet rotor. In the subject helicopter, the ratio of rotor thrust to jet thrust was 12.7, which figure remained substantially invariant within the normal rotor operating range.

(e) *Rotor Blades*

The rotor-blade construction appeared to be ideal for pressure-jet application. A circular steel tube of 2 in. inside diameter, 4 ft. in length, connected the hub to the airfoil section. It did not carry the centrifugal forces but served other important structural functions

of furnishing the necessary torsional stiffness to transmit feathering control moments, acting as a compression member when the blades rested on their droop stops, and supplying the rigidity in bending moment about the flapping axis. The blade proper was of monocoque construction, being a hollow aluminum extrusion of roughly elliptical cross section, with a wooden trailing edge cemented directly to it. A constant chord NACA 23018 airfoil section was used. A small groove in the trailing edge of about 0.3 in. diameter accommodated the ignition cable leading to the tip burner. Connection between the steel tube and the airfoil was somewhat intricate, but structurally and aerodynamically clean: overlapping steel sleeves were flush riveted inside and out onto the aluminum airfoil without obstructing the internal airflow. This riveting arrangement was repeated at the outboard end of the airfoil, where it terminated with a stainless steel cuff (see Fig. 4). A group of tubes with V-type "gutter" flame arresters was inserted at this point, protruding about 3 in. from the blade. This was the flame holder. The tip-burner housing fitted over the tube ends and was clamped to the blade by an ingenious double-grooved strap. The burner was made of 0.1-in. thick stainless steel, cast in two halves and welded along the horizontal parting line. The jet orifice was circular and sharply converging, causing a pronounced vena contracta to occur with as well as without burning. It was also notable that the centerline of the jet formed about 7° with the airfoil at the tip. In this manner, jet thrust was kept almost exactly tangential when the blades were in hovering pitch. Conversely, jet thrust had a negative incidence when the blades were in flat pitch.

A small automotive spark plug, with its outer electrode removed, was placed in the trailing edge of the burner. At this point the duct sharply increased in area to produce highly turbulent stagnant air in the corner where the firing end of the spark plug was located. The body of the plug was cooled by external air. Flame-holding characteristics of this burner were excellent; ignition was not difficult; reignition at full power was good, once the jets were warmed up.

In spite of good combustion characteristics, the tip burners were responsible for the largest single loss in the thermodynamic cycle. Up to 20 per cent loss of total pressure occurred at this point, due to large "blockage" ratio of the flameholder and the "hot" 90° turn of low aspect ratio. However, combustion efficiency was consistently better than 90 per cent.

Contrary to previous reports, Doblhoff tip burners were not operating as true pulse-jets, and the blades did not resonate similarly to organ pipes. Our experience with a large variety of constant-pressure burners indicated that Doblhoff burners behaved much like open-duct constant-pressure burners. While the average compression ratio of a "constant volume" pulse-jet may be as high as 2.5:1, the pulse contribution to the compression ratio in the Doblhoff burners was estimated to be less than 1.2:1. Most constant-pressure burners readily "resonate" at a number of frequencies, depending

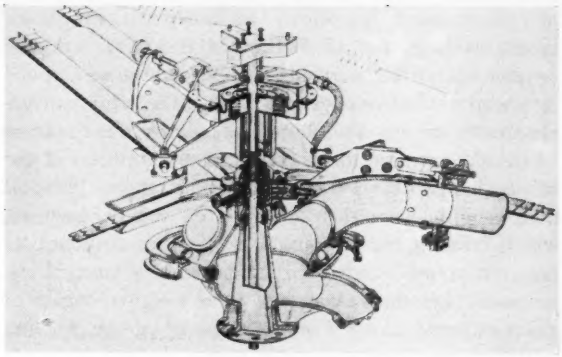

FIG. 16. Rotor hub design.

upon the air-fuel ratio, detonation properties of the fuel, and the characteristic distances between the fuel injection, the flameholder, and the exit nozzle. However, mass flow and jet thrust measurements, with due account to the various efficiencies, indicated a nearly constant-pressure combustion. In the case of Doblhoff burners, the characteristic distance was definitely between the flameholder tubes and the exit nozzles and not the whole blade. The advantage of maintaining a resonant pulsation within the constant-pressure burner, when not detrimental, lies mainly in better mixing, scavenging, and more rapid flame propagation, which was reflected in improved combustion efficiency and smaller burner volume. Per cent modulation of the pulse tone in the general noise level was not high. It was interesting to note that when the blades as a whole did break into the resonance, as occasionally happened during the starts, pressure waves immediately blew out the flames in all burners. It took several seconds for these standing waves to decay. Fortunately, this happened only at low power settings and was unlikely to occur in flight, except in partial power descents.

In passing it may be worth mentioning that burner flame-out did not produce appreciable unbalance on the rotor, since with one burner gone, all three jets lose power simultaneously. In fact, so imperceptible was the change in balance, the pilot as a rule had to be informed of the flame-out by the people standing outside of the rotor periphery. In flight, of course, the sharp drop in rotor power would be immediately observed, but the reason for it would not be evident to the pilot unless the burners were equipped with indicating thermocouples.

The surface of tip burners was red hot during the operation, even at full rotating speed, but the flame itself was barely visible. Thermal stresses throughout the burners were extremely high, which was evidenced by a number of cracks that appeared here and there on their surfaces almost incessantly. It was our practice to inspect and magnaflux the burners every 2 hours and to fill the cracks about every 5 hours. Of course, it should be remembered also that the exit temperatures were nearly 3,900°F.

Chordwise balance of each blade was originally brought to 35 per cent from the leading edge by means

of a single nose weight located at 70 per cent of the blade span. It consisted of a sheet-steel sleeve wrapped around the airfoil, carrying a solid steel nose about 4 in. ahead of the leading edge. When the rotor was mechanically driven, the chordwise balance was found to be insufficient, due to lowered torsional stiffness of the suspension and early occurrence of flutter. Additional nose weights were then installed on the tip burners, which brought the average mass balance to about 23 per cent chord. During dynamic testing later in the program, one of the original nose weights began to creep outward along the blade, buckling the wooden trailing edge ahead of it. A thorough inspection revealed an unsafe condition of the weights and the trailing edges, whereupon all original counterweights were removed. Subsequent tests showed that tip weights provided adequate blade balance, since no flutter occurred through full range of rotor speeds.

(*f*) *Air-Fuel Ratio Regulator Valve*

As could be expected, premixing of air and fuel far ahead of the combustion chambers necessitated an automatic air-fuel ratio control. Limits of flammability of a homogeneous mixture are rather narrow, and, as a rule, the flame was sustained with difficulty at air-fuel ratios above 20:1. Therefore, an automatic valve was provided to maintain a nearly constant air-fuel ratio at all power settings. Fuel metering was done by a needle valve that was actuated in response to air pressures in the hub. Although the relationship is not linear, higher pressure in the hub was an indication of higher air mass flow and therefore called for higher fuel flow. The needle valve was actuated by a 6-in. diameter diaphragm, one side of which was acted upon by the compressor outlet pressure, and the other side was vented to atmosphere.

While fairly satisfactory mechanically, functional operation of the valve still left much to be desired. When the jets were not ignited, hub pressure was low and, therefore, the mixture was too lean. When the jets suddenly ignited, the valve delivered a surge of rich mixture. Finally, when one of the jets blew out in flight, the mixture was automatically leaned out in the remaining two jets, causing further loss of power or a complete flame-out.

(*g*) *Fuel Vaporizer*

As mentioned previously, the Doblhoff power cycle required two types of fuel: (1) high-octane fuel for the piston engine and (2) low-octane, low-vapor-pressure fuel for tip burning. By designers' choice, the latter was injected in a vaporized state into the air stream, just beyond the compressor outlets.

A rather ingenious heat exchanger, described by other authors as "the boiler" or "the kettle," made use of waste heat from the piston engine exhaust to vaporize the jet fuel. The vaporizer proper consisted of a 4-in. diameter exhaust stack, housing 40 quarter-inch outside diameter fuel tubes connected in parallel to headers on each end of the enclosing stack (see Fig. 3). The entering liquid fuel first flowed horizontally inside the small diameter tubes and then turned vertically upwards. There it was collected in vapor state in the header on top of the vertical portion of the stack and hence was fed into the compressor outlets. Average temperature of the preheat, under rated conditions, was 350°F.

To prevent vapor lock and formation of large bubbles, soft copper wires about 0.06 in. in diameter were inserted through the full length of each of the 40 fuel tubes. High specific conductivity of copper also helped to eliminate hot spots in the vaporizer.

Generally, the vaporizer operated satisfactorily under rated conditions. However, it was one of the components that required constant attention. There were several reasons for this:

(1) Frequently, the back pressure at the vaporizer outlet was high enough to blow the liquid fuel backwards through the fuel pump into the fuel tank. Whether this was due to excessive clearances in the pump or to uncontrolled pressure build-up in the header was not ascertained. This situation could become embarrassing in flight when hovering at moderate altitudes. Frequent recurrence of this condition led to the installation of a bleeder valve at the vaporizer outlet which permitted pressure relief and discharge of fuel vapor into the atmosphere. The valve was manually operated. Once the fuel flow was re-established the bleeder valve could be closed, and fuel continued to flow in the proper sense.

(2) By virtue of gradual increase of pressure drop across the vaporizer due to carbon accumulation in its tubes, the air-fuel mixture valve continually changed its calibration toward the leaner side. This in itself was not too objectionable, although peak-power performance was not available with partially clogged vaporizer; it merely made reproducibility of power tests more difficult. In practice, the vaporizer tubes were cleaned out every 5 hours of operation.

(3) At idling speed, exhaust gases generally did not carry enough heat to completely vaporize the jet fuel in spite of a considerable spark retard introduced expressly for this purpose. Unless the exhaust stacks were preheated at about half engine power for a short time prior to firing the jets, fuel was likely to reach the tip burners in liquid form. When ignited, it burned outside the jet nozzles in typical flame-thrower fashion, supplying little thrust, and was incapable of being swallowed back into the combustion chambers even after properly vaporized fuel reached the tips. When this occurred, tip combustion had to be completely shut down and the starting procedure repeated.

(4) In its actual execution, the vaporizer could not be by-passed by the exhaust gases, making it impossible to run-up the engine without simultaneously feeding the jet fuel. Otherwise, vaporizer tubes became red hot and disintegrated rapidly. An exhaust by-pass should be definitely a part of this type of installation.

(5) Only a low-boiling-point, leadless, low-octane gasoline was found suitable for the jet fuel. More vaporizing heat was required for higher boiling point fuels, such as kerosene; this resulted in higher surface temperatures and still higher rate of carbon deposit. Moreover, kerosene and JP fuels partially condensed on the walls of ducts and blades and were ultimately ejected into the atmosphere in the liquid form, unburned. Higher octane gasoline was also tried in an effort to use only one type of fuel, but it was found to produce unnecessarily long flames accompanied by a marked reduction of jet thrust, or it refused to sustain combustion within the burner altogether.

(6) As appealing as the prevaporizing scheme may seem from the combustion standpoint, it was chiefly responsible for the poor economy of the Doblhoff power cycle at partial power. Had the tip temperature and jet area been made controllable, the engine could be continuously operated at maximum power, while the more wasteful jet fuel could be reduced to obtain reduced power. Specific fuel consumption would then improve, instead of becoming worse, at partial power. Premixing of air with fuel, however, ruled out this possibility by narrowing down the range of operable air-fuel ratios.

(*h*) *Overall Operation*

The integrated power plant, composed of all the above components, behaved reasonably well in steady-state, full-power operation, though it was cranky and not too reliable outside of rated conditions. As an autogiro with hovering take-off, however, it was not intended to operate much outside of rated conditions. Although the theory indicates that rotor horsepower under jet drive can equal and exceed by a large margin the installed engine horsepower, Doblhoff's power plant failed to accomplish it, mostly because of unfortunate compromises and large losses throughout the system.

From the standpoint of weight-saving, none was in evidence in the Doblhoff helicopter, compared to shaft-driven helicopters or autogiros of equal horsepower or weight. Therefore, even on the basis of intermittent use of the jet drive, the Doblhoff power plant, as executed in the WN 342 machine, did not meet the competitive weight standards already established in the rotary wing field.

This finding should not be taken as a basis for condemnation of pressure-jet cycles, for the picture could be completely reversed by the use of gas turbines as air generators, for instance, or by another more efficient mechanical arrangement of basic components.

(*i*) *Conclusion*

The contribution of the Doblhoff power plant rests mainly in pioneering the central pressure-jet power cycle and in proving its workability. It deserves the credit for having demonstrated for the first time, on a flying article, the torqueless propulsion principle, and, as such, it will remain an historic landmark in the annals of helicopter engineering.

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Boundary-Layer Studies on a Sailplane

AUGUST RASPET*

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Forward

In sailplane development we have only one possible avenue for improvement, that of reducing aerodynamic losses. In powered aircraft there is in addition to this the possibility, all too often applied, of increasing power. This latter does not, in general, add anything but speed and climb, whereas pay load and range—the real economic considerations—are not affected, except possibly adversely.

To the sailplanist striving for long cross-country flights, there is available only one power source—the sun. The utilization and exploration of means for extracting solar energy by the sailplane have resulted in performance improvement even when a reduction of aerodynamic losses was not made. However, the sailplanist who has consistently sought aerodynamic perfection will, in general, be able to soar the longest distance.

For many years sailplane designers followed the thesis that increased aspect ratios would, in general, result in better cross-country soaring ability. Efforts were made simultaneously to reduce drag by eye-appealing curves. The first rational approach to sailplane design was that of Lippisch in the São Paulo, for which the intersection of the wing and fuselage was computed following the theory of Muttray.

Recently, however, careful analysis of flight-test performance measurements has led progressively to a consideration of means for first preventing the separation of the turbulent boundary layer in the wing root and then preserving a laminar boundary layer over as much of the surface of the sailplane as possible. Although this technique is not yet exhausted, the approach has pointed out the benefits of applying artificial controls to the boundary layer. The reason for this trend is that the benefits of boundary-layer control are more apparent on an aircraft already possessing an extremely low drag. For example, on the currently outstanding American sailplane RJ-5, the profile drag coefficient is 0.0065 and the parasite drag coefficient is 0.0055. A reduction of the profile drag by 50 per cent is felt as an increment of about 25 per cent in the overall minimum drag. What is more, the same technique could be applied to the fuselage and tail surfaces, thereby reducing the total drag by 50 per cent.

In view of the foregoing considerations, it is clear that aerodynamic research in motorless flight should be aimed at boundary-layer research.

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* Sailplane Project Leader.

It should, however, be shown that the sailplane possesses some special advantages over even the low-turbulence wind tunnel for boundary-layer research. It has been pointed out by numerous boundary-layer researches that noise, because it is a pressure fluctuation, can act as a cause of transition. Around a low-loss sailplane, the noise level is much lower than that in most wind tunnels. In addition, the turbulence of the free atmosphere has been shown to have an insignificant effect as a cause of transition. The powerful source of vibration, the engine, is absent, and only the vibration induced by aerodynamically unsteady flows is present. This is of an extremely low level.

Coupled with these primary advantages of the sailplane are those of mechanization of a test section. It is relatively simple and quick to modify a section to a new airfoil by planking with balsa over the original contour. By filling with putty and sanding, the contour can be made stable and wave-free to the desired geometric precision.

The following paper is offered as an example of the unique possibilities of the sailplane in boundary-layer research. The author gratefully acknowledges the financial support of this study by the Office of Naval Research. He also wishes to express his appreciation for the excellent collaboration of the members of the Air Branch of the Office of Naval Research. The author is particularly grateful to his research team, whose cooperation in this study was invaluable.

Symbols

ΔC_L	=	increment in lift coefficient
ΔP	=	static pressure on wing tip
C_Q	=	suction flow coefficients $C_Q = Q/V_S$
Q	=	quantity of air flow, cu.ft. per sec.
V	=	air speed, ft. per sec.
S	=	area of wing over which suction is applied
C_p	=	pressure coefficient p/q
q	=	dynamic pressure
p	=	static pressure in wing
u	=	velocity component in boundary layer parallel to airfoil surface
U_0	=	free-stream velocity
v_0	=	inward suction velocity at airfoil surface
y	=	coordinate perpendicular to airfoil surface
ν	=	kinematic viscosity of fluid

Introduction

In 1924 Betz[1] showed that on an airfoil with a rounded trailing edge the location of the rear stagnation point determines the lift coefficient of the airfoil. This was demonstrated by means of a conformal transformation and is for this reason a potential solution. The effects of viscosity on the flow were not considered.

In 1941 Regenscheit[2] reported experimental data on a technique of influencing the position of the rear stagnation point by means of suction at the trailing edge. By this means it was possible to increase the lift coefficient without an increase in angle of attack.

Subsequently, Regenscheit[3] reported trailing-edge suction as a means for drag reduction. By obtaining the power required for suction from the low pressure at the wing tip, Regenscheit developed what he termed "automatic suction."[4] In a postwar paper,[5] Regenscheit summarizes his most recent thinking on the aerodynamic behavior of automatic trailing-edge suction for lift augmentation and drag reduction. He carefully clarifies the fact that trailing-edge suction is not a laminar boundary-layer stabilizing method but rather a method for pressure drag reduction.

Walz,[6] in a systematic series of wind-tunnel results, showed that the suction flow quantity for a given increment in lift coefficient was a minimum when the slot was placed at about 10 per cent of the chord from the leading edge. He also showed only a small reduction of total drag (profile drag due to power needed for suction) for the slot placed near the trailing edge. This reduction of profile drag is, according to Walz, of the order of 10 per cent, being greater at the lower angles of attack. Since few blower and duct systems would have efficiencies greater than 90 per cent, one is led to conclude that the overall gain would be zero or negative.

This contradiction by Walz of Regenscheit's evidence that trailing-edge suction reduces drag indicates that Walz either did not have an optimum slot design or else the claim made for the drag reducing properties of trailing-edge suction by Regenscheit is not valid.

Examination of the wind-tunnel results for lift augmentation shows considerable variation of the amplification factor $\Delta C_L/C_Q$ as computed from the results of Regenscheit,[7] Walz,[6] and Smith.[8]

In view of the contradictions pointed out for both the concept of drag reduction and that of lift augmentation, the study described in this paper began first with an examination of the mechanism of trailing-edge suction. The study was planned to determine whether trailing-edge suction exercised any control over the laminar boundary layer or prevented the separation of the turbulent boundary layer near the trailing edge.

Concurrently, experimental studies on the source for automatic trailing-edge suction were carried out. Although Regenscheit showed several variations of wing-tip suction sources in his early papers, he was not convinced that these were the best, for, in his postwar paper,[5] he adopted the suggestion of Lippisch[9] that the low-pressure region on the upper surface of a square wing tip be used for automatic trailing-edge suction. Even with this configuration, a knowledge of the position of this low-pressure region under various lift conditions is needed. When a particular region of the tip is selected as a suction source, it will be necessary to determine its properties when an outward flow takes place through an opening in that region. With a knowledge of these facts it will be possible to couple the wing-tip source to the trailing-edge slot and obtain predictable results in lift augmentation.

FIG. 1. Boundary-layer research sailplane.

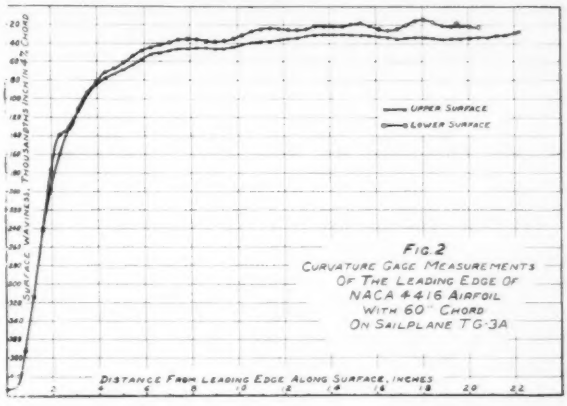

FIG. 2
CURVATURE GAGE MEASUREMENTS OF THE LEADING EDGE OF NACA 4416 AIRFOIL WITH 60" CHORD ON SAILPLANE TG-3A

EXPERIMENTAL ARRANGEMENT

The apparatus used in this study for investigating the mechanism of trailing-edge suction consisted of a TG-3A war surplus sailplane, Fig. 1. The rear cockpit served as the observer's post. On the left wing of this sailplane, a section (45 in. wide by 60 in. chord) of the airfoil (NACA 4416) was prepared as the test area. The plywood leading edge on the top surface was carefully contoured by filling it with putty and sanding. It was made wave-free to ± 0.002 in. measured over control points 2.4 in. apart. Near the spar at 35 per cent fabric replaces the plywood. In order to prevent a sharp discontinuity in curvature, false ribs and small riblets were installed directly behind the plywood leading edge. The false ribs extended to the trailing-edge slot, but the riblets were only 3 in. long.

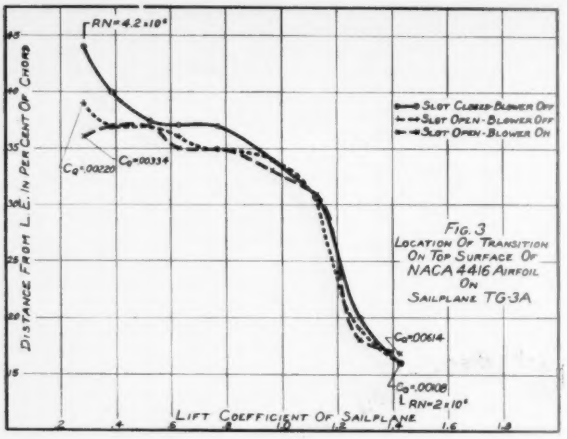

FIG. 3
LOCATION OF TRANSITION ON TOP SURFACE OF NACA 4416 AIRFOIL ON SAILPLANE TG-3A

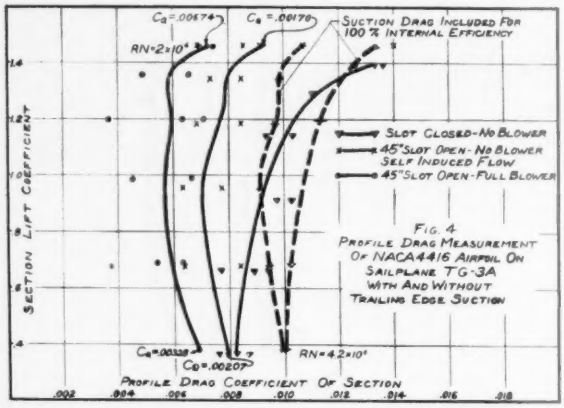

FIG. 4
PROFILE DRAG MEASUREMENT OF NACA 4416 AIRFOIL ON SAILPLANE TG-3A WITH AND WITHOUT TRAILING EDGE SUCTION

Near the trailing edge is a traversing wake pitot for measuring profile drag, as shown in Fig. 1. The observer is shown wearing a stethoscope that is connected to the long tube over the wing. On the outer end of this tube is a small diameter pitot probe that is placed onto the airfoil when it is desired to make an observation of the nature of the boundary layer. If the flow is turbulent, the observer hears a loud rushing noise in the stethoscope. By moving the probe forward over the airfoil, a region is found where only occasional bursts of turbulence are heard. This is the transition region. Further forward in the laminar flow the observer hears only a gentle hissing noise. The field of boundary-layer research owes the introduction of this instrument to Pfenninger.[10]

Inside the cockpit of the sailplane a battery-driven blower was used for applying controlled suction to the trailing-edge slot seen near the trailing edge in Fig. 1. This slot was arranged so that changes in slot shape could easily be made by adding variously shaped inserts.

By means of this experimental tool it is possible to determine, in one gliding flight from 7,000 ft. of altitude, the position of transition as a function of lift coefficient and of suction pressure inside the wing. Flights were started at dawn when the turbulence due to convection in the atmosphere was generally completely absent. Another feature that the sailplane offers the boundary-layer research worker is the low level of noise, which can act as a cause of early transition.

Drag Reduction

In order to determine whether trailing-edge suction offers any stabilization to the laminar boundary layer, a series of transition measurements was made with the stethoscope and with various amounts of flow into the slot, a diffuser type located between 96.5 to 98 per cent of the chord. In Fig. 3 are shown the results of this exploration. It is clearly evident that, if anything, suction at the trailing edge tends to move the transition forward. This may be due to the slight deflection of fabric near the rear edge of the plywood leading edge. In any case, here is conclusive proof that the effects of the trailing-edge suction do not extend far enough forward to influence the laminar boundary layer. In view of this behavior, any drag decrease that may be claimed for this aerodynamic technique must be due to a reduction of pressure drag as mentioned by Regenscheit.[5] Since this pressure drag is a function of boundary-layer thickness, however, one must conclude that the remaining explanation for a possible drag reduction is a control of the separation point on the airfoil. This is clearly demonstrated by the drag measurements of Fig. 4. These measurements were made by measuring momentum loss of the wake and then adding the power required for suction:

$$C_{D_t} = C_{D_p} + (1 - c_p)\, C_Q$$

Only at high lift coefficients and at low flow coefficients is there an overall drag reduction. This behavior is clear proof that trailing-edge suction alone merely prevents turbulent boundary-layer separation. Perhaps a careful determination of the optimum flow would show a slightly greater drag decrease than that of the present data. Furthermore, there is no reason to assume that the slot used could not be improved.

Another point that should be emphasized is the following: If the suction power can be obtained from a source without resulting in additional drag, then the method of Regenscheit can be considered a drag-decreasing technique. In this connection it must be remembered that literally "swallowing" the wake into the wing is tantamount to taking away the low momentum flow that is a measure of profile drag in the momentum-loss-measuring technique.[11]

Lift Augmentation

Since the claims made for the drag-reducing effect of trailing-edge suction do not appear to be solidly supported by experimental or theoretical evidence except when separation exists, it is necessary to examine in the same manner the lift-augmenting characteristics of trailing-edge suction if a decision on the utility of the process is to be made. A simple criterion for the efficiency of any suction or blowing technique is the ratio of lift increment to flow coefficient, which may be called an amplification factor $\Delta C_L / C_Q$. In Table 1 are given

various sources of data and the pertinent data from which the lift amplification factor has been computed.

Examination of Table 1 shows considerable inconsistency among the amplification factors obtained. In particular, it appears that a slot at 10 per cent would have the highest influence on the lift for a given quantity of flow. If the power required for moving air through the slot is considered, however, one finds this slot position not as advantageous as a trailing-edge slot. This behavior is due to the fact that a much greater suction pressure is required to induce a flow against the high negative pressure peak on the wing at the forward position.

For trailing-edge suction, Regenscheit's results for the amplification factor appear much higher than Smith's[8] theoretical or experimental results. Smith's theory does show that $\Delta C_L/C_Q$ rises rapidly as the slot approaches the trailing edge. In a recent work, Ringleb[13] showed also that the slot shape is an important parameter for influencing the va ue of $\Delta C_L/C_Q$.

Fig. 5 shows the increment in lift which is obtained at various dynamic pressures with a slot between 97 and 98 per cent of the chord on an NACA 4416 airfoil. This is a flight measurement made by integrating the pressure distribution around the airfoil with various suction flows into the slot. It will be observed that $(\Delta C_{L_{max}}) = 0.030$ for $C_Q = 0.0045$ which yields an amplification factor of only 6.7. Although this value agrees in magnitude with Smith's, there are two possible reasons for such a low amplification factor: the first and more likely is the loss of pressure into the region of the wing not equipped with a slot (the test section only 45 in. wide represents only 8 per cent of the wing area); the second is that the slot design may not have been the optimum. It is planned as the next stage in this research to fit a complete wing with a trailing-edge slot of Ringleb's design in order to determine by free-flight measurement the practicability of trailing-edge suction as a lift augmenting means.

TABLE 1

Source	Fig. No.	Slot Position	ΔC_L	C_Q	$\frac{\Delta C_L}{C_Q}$
FB 1474	5	Trailing edge	0.5	0.0050	100
FB 1611	16	10 per cent	0.2	0.0010	200
FB 1611	16	21 per cent	0.4	0.0026	154
FB 1611		25 per cent	0.6	0.0040	150
FB 1611		27 per cent	0.8	0.0058	138
FB 1611		29 per cent	1.0	0.0076	131
FB 1611	18	20 per cent	0.18	0.00075	240
FB 1611			0.30	0.0015	200
FB 1611			0.50	0.003	167
FB 1611			0.65	0.005	130
FB 1611			0.90	0.007	128
FB 1550	11e	Trailing edge	0.8	0.008	100
	12	Trailing edge	0.5	0.005	100
Reference 8	8	95 per cent experimental	0.14	0.004	35
	8	95 per cent theoretical	0.07	0.007	10
FB 1274 Blowing Reference 12	20		0.11	0.005	22
			0.34	0.010	34
			0.82	0.020	41

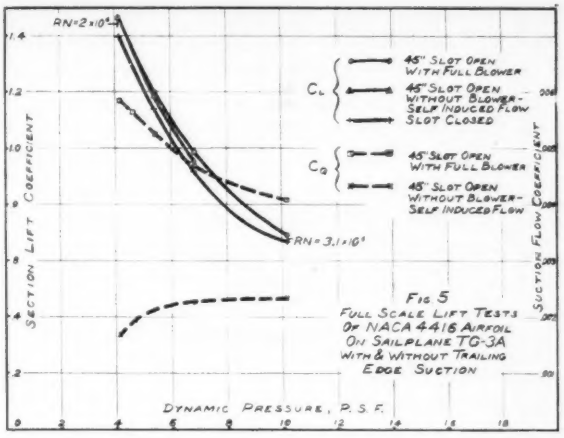

FIG. 5 FULL SCALE LIFT TESTS OF NACA 4416 AIRFOIL ON SAILPLANE TG-3A WITH & WITHOUT TRAILING EDGE SUCTION

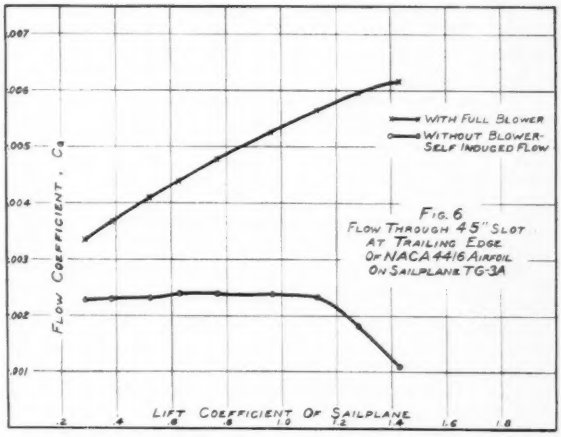

FIG. 6 FLOW THROUGH 45" SLOT AT TRAILING EDGE OF NACA 4416 AIRFOIL ON SAILPLANE TG-3A

The nature of the two types of suction used in the trailing-edge suction test of Fig. 5 is shown in Fig. 6. The self-induced suction resulted from a low-pressure region near the tail of the sailplane used for these tests. The outlet to the free stream was located in this region. The flow from the wing exhausts into the fuselage, through which the flow exhausts from the opening near the tail.

AUTOMATIC SUCTION

An interesting means for obtaining the suction power required for trailing-edge suction was developed by Regenscheit.[4] He proposed and showed by wind-tunnel measurements that an opening near the wing tip of an airfoil can act as a suction source for trailing-edge suction. At the tip the additional velocity due to the tip vortex results in a low-pressure region into which the flow from the trailing-edge slot may be exhausted.

It was first thought that a streamlined body of revolution on the tip would provide a good suction source. The idea here was to cut off a portion of the trailing edge of the streamlined body and place the body in the center of the tip vortex. In Fig. 7 are given the pressure distributions around such a tip body. A maximum suction pressure of $0.5q$ is obtained near the rear tip of the body. On the side, however, there is an extensive

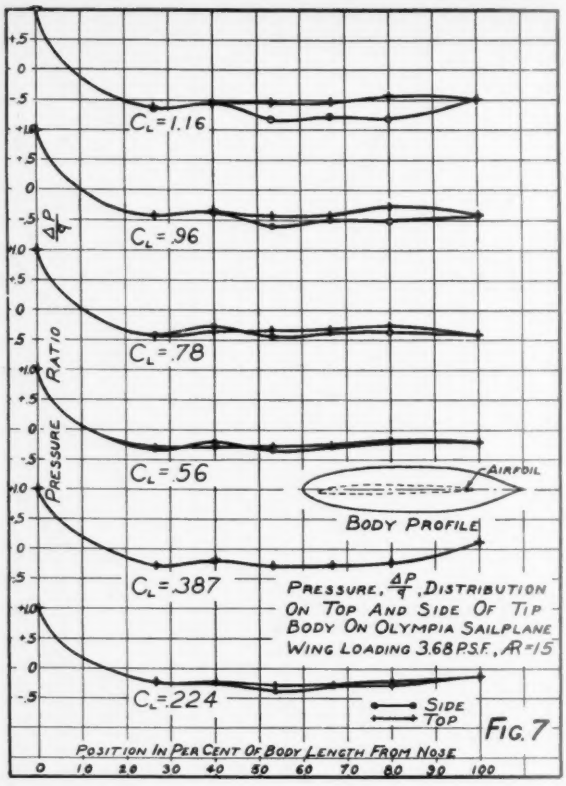

FIG. 7

region at high lift coefficients which yields a pressure of $-0.8q$.

Another possibility as a source of suction is the secondary low-pressure region found on the upper surface toward the trailing edge of the tip of an airfoil.[14] A tip consisting of a rounded leading edge and a square trailing edge was fitted to the same sailplane used in the tip body tests. Explorations of pressure made at various lift coefficients resulted in the isobar maps shown in Fig. 8. The region at $C_L = 1.16$, having a pressure of $-1.6q$, appears promising as a source of automatic trailing suction when used for lift augmentation.

In selecting a suitable suction source, one must also consider the influence of the flow from an opening in the tip. In other words, the pressure at the source must be known for various flow quantities. It is planned as part of this research to evaluate the tip shown in Fig. 8 under various flow rates.

Stabilization of the Laminar Boundary Layer by Porous Suction

In the lift augmentation studies made in the first section of this paper, the flow into the slot was turbulent for all lift coefficients. Since the theoretical computations made by Smith and Ringleb were based on potential flow, it appeared that a flow with a laminar boundary layer would most closely approach the potential flow.[15] Therefore, in an effort to delineate the influence of the boundary layer on the lift augmentation of trailing-edge suction, the following research on laminar boundary-layer stabilization was initiated.

The use of suction as a boundary-layer stabilization means was first suggested by Prandtl in 1904. Later theoretical works by Ulrich,[16] Schlichting,[17] and Iglish[18] showed that the suction flow required for stabilization of flow over a flat plate was small, of the order of 10^{-4} times the free-stream velocity over the surface. An excellent survey of the problem on airfoils is contained in the von Doenhoff and Loftin paper.[19] The work of Pfenninger[20,21] exemplifies the best achievement obtained so far with spanwise slots on an airfoil. Pfenninger and von Doenhoff and Loftin point out the difficulties of producing and designing correct slots. In view of these difficulties, there has been a tendency of various research workers to favor area or porous suction over suction through slots (see reference 22 for an example of research on area suction). For the present research, a simple technique consisting of an intermediate solution between area and slot suction was developed. In essence, this technique consists of spanwise lines of closely spaced holes pricked into the aircraft fabric with which the after portion of the test airfoil was covered. Since this technique proved to be economical with respect to suction quantities, it is planned to extend the study to include suction over the plywood leading edge.

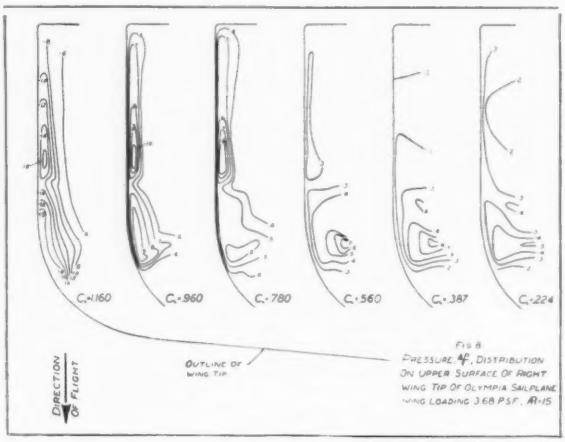

FIG. 8 PRESSURE $\frac{\Delta P}{q}$ DISTRIBUTION ON UPPER SURFACE OF RIGHT WING TIP OF OLYMPIA SAILPLANE WING LOADING 3.68 P.S.F. AR=15

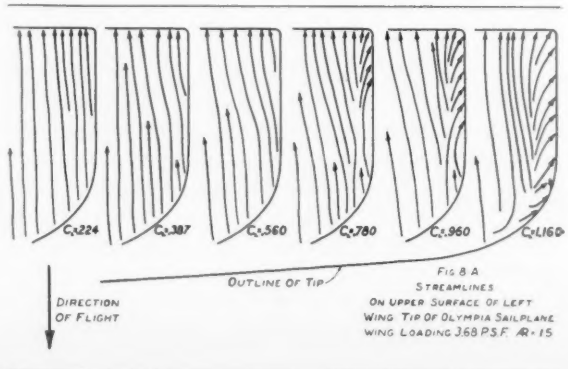

FIG. 8 A STREAMLINES ON UPPER SURFACE OF LEFT WING TIP OF OLYMPIA SAILPLANE WING LOADING 3.68 P.S.F. AR=15

Considerations on Porous Suction Through Lines of Holes

It is well known that the turbulent boundary layer cannot readily be restored to a laminar one. In reference 20 the statement is made that no amount of suction applied downstream will restore a laminar boundary layer once turbulent flow has set in. It can safely be said that to establish laminar flow in a region already turbulent would require at least the removal of the complete boundary layer. There appears to be no experimental or theoretical guidance to show just how much suction is required for this process.

In line with the foregoing fact, it was found necessary to contour the leading edge of the test airfoil to a waviness of ± 0.002 in. on gage points 2.4 in. apart in order to maintain the boundary layer laminar far enough behind the spar for the porous area (A) in Fig. 9 to be effective in stabilizing the flow. When the leading edge was made wave-free, as shown in Fig. 2, the flow behaved as shown in Fig. 3. This figure shows that at any lift coefficient below 0.93 the flow was laminar to the rear edge of the spar at $0.345c$. With this laminar extent porous suction should be able to stabilize the flow up to lift coefficients of 0.93. Above this lift coefficient the flow will be turbulent in spite of the area suction applied to the turbulent boundary layer.

Fig. 9 shows a transition curve without suction but with the area porous in zone A. This transition curve, when compared to that for the impervious wing in Fig. 3, shows that the porous zone A acts as a destabilizing element when local outflow is permitted to take place through the porous zone. This behavior is confirmed by the work of von Doenhoff and Loftin.[19] Fig. 9a shows the line of transition on the upper surface of the research sailplane. The line of transition is indicated by the selective evaporation of dew that had deposited on the wing just prior to take-off. It will be seen that in the test area transition occurs at the front edge of the porous area. Since there is no suction pressure applied, transition occurs at the forward region where local outflow exists. In view of this behavior, the application of porous suction to long-range aircraft will require a safeguard in case the suction pump should fail. This safeguard might be a porous material having a much higher resistance to outward flows than to inward. With such a material, the airfoil will at least not be worse than an impervious airfoil if the suction should fail.

Examining Fig. 9 in more detail, the reader will see that area B was added to the highly porous area. The original intention of the highly porous zone A was to stabilize the flow to a high degree and then, after this initial boost, to apply just enough suction to carry the laminar flow into the next zone. The same procedure was carried out to zone D, but no measurements of the degree of stability were made. It is planned as a continuation of the present work to make measurements of the displacement thickness of the boundary layer in order to determine if the asymptotic velocity distribu-

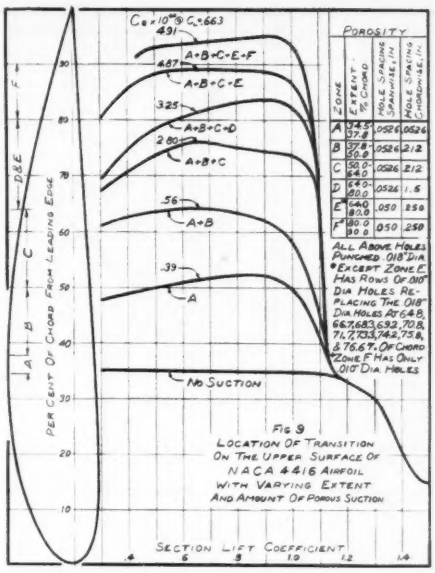
$C_R = 10^6$ @ $C_L = .663$
.491
A+B+C+E+F
.487
A+B+C+E
.325
A+B+C+D
.280
A+B+C
.56
A+B
.39
A
No Suction
Per Cent Of Chord From Leading Edge
Section Lift Coefficient
Porosity
Zone | Extent % Chord | Hole Spacing Spanwise, In | Hole Spacing Chordwise, In
A | 34.5 - 37.8 | .0526 | .0526
B | 37.8 - 50.0 | .0526 | 2.12
C | 50.0 - 64.0 | .0526 | 2.12
D | 64.0 - 80.0 | .0526 | 1.5
E | 64.0 - 80.0 | .050 | 250
F | 80.0 - 90.0 | .050 | 250
All Above Holes Punched .018" Dia.
*Except Zone E, Has Rows Of .018" Dia Holes Replacing The .018" Dia Holes At 64.8, 66.7, 68.3, 69.2, 70.8, 71.7, 73.3, 74.2, 75.8, & 76.67% Of Chord
*Zone F Has Only .018" Dia Holes

Fig 9
Location Of Transition On The Upper Surface Of NACA 4416 Airfoil With Varying Extent And Amount Of Porous Suction

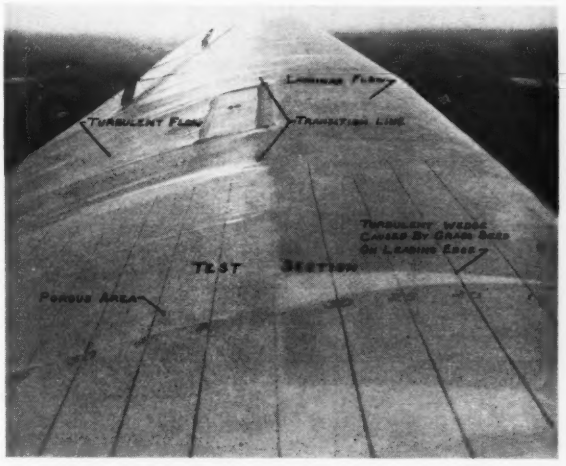

Fig. 9a. Demonstration of transition by dew evaporation method on sailplane TG-3A at $C_L = 0.681$ with suction blower off.

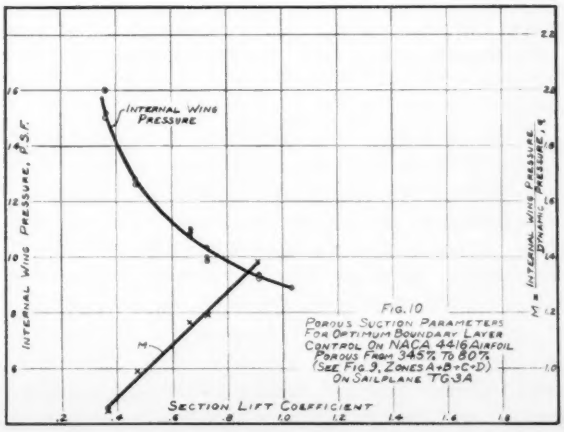
Internal Wing Pressure
Internal Wing Pressure, P.S.F.
M = Internal Wing Pressure / Dynamic Pressure, q
Section Lift Coefficient

Fig. 10
Porous Suction Parameters For Optimum Boundary Layer Control On NACA 4416 Airfoil Porous From 34.5% To 80% (See Fig. 9, Zones A+B+C+D) On Sailplane TG-3A

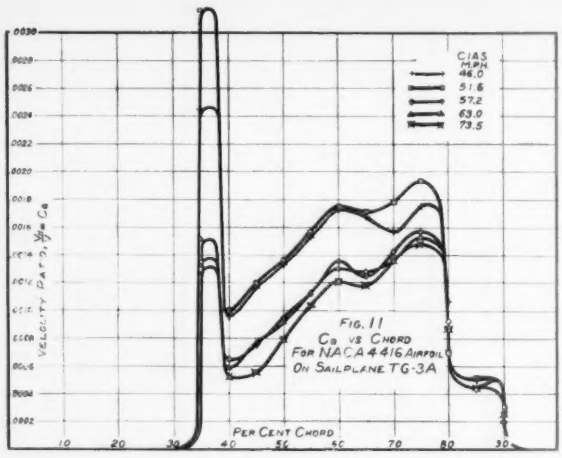

FIG. 11
C_Q VS CHORD
FOR NACA 4416 AIRFOIL
ON SAILPLANE TG-3A

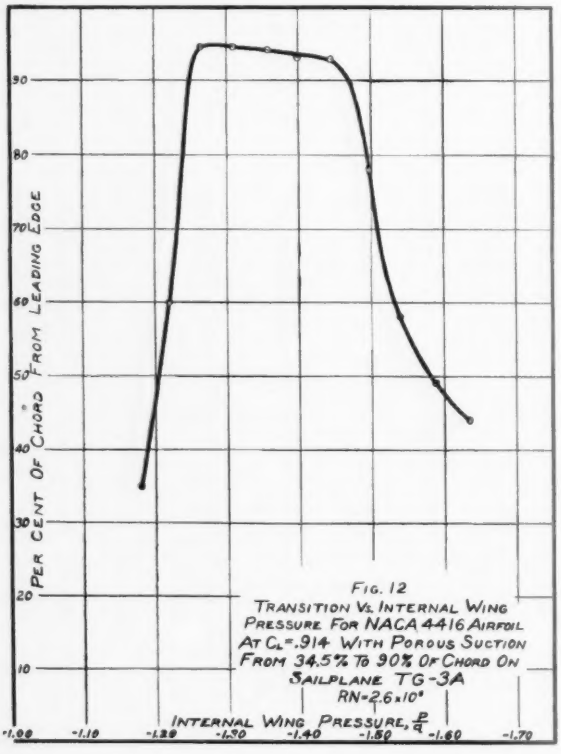

FIG. 12
TRANSITION VS. INTERNAL WING PRESSURE FOR NACA 4416 AIRFOIL AT C_L=.914 WITH POROUS SUCTION FROM 34.5% TO 90% OF CHORD ON SAILPLANE TG-3A
RN=2.6×10⁶

tion is obtained, $u/U_0 = \{1-e\ [(-v_0 y)/\nu]\}$, where v_0 is the inward suction velocity. By this means the distribution of porosity for optimum suction will be determined.

In zone D in Fig. 9, the lines of holes were spaced at 1.5 in. This spacing would yield a $C_Q = 2.0 \times 10^{-4}$ or just about two times that computed by Ulrich[16] for stabilization of the laminar boundary layer on a flat plate. When suction was applied through zones A+B +C+D, it was found that the boundary layer was laminar only a short distance beyond the aftermost line of holes at 80 per cent C. This means that if the next line of holes were placed 1.5 in. downstream they would be in turbulent flow and could not exercise a stabilization of the boundary layer. Consequently a series of lines of holes of 0.010-in. diameter were placed at 0.5-in. spacing. These did not materially improve the laminar extent. When the number of lines of holes was increased so that the lines were spaced 0.25 in., however, stabilization was achieved. This behavior indicates a critical spacing of the lines of holes. A more refined determination of the relations between spacing of the lines, boundary-layer stability, and suction is needed in order to be able to predict a design utilizing lines of holes.

The last zone, F, was pricked with only 0.010-in. holes with a row spacing of 0.25 in. Control of the laminar boundary layer was established to a sufficient degree to carry the laminar flow to slot at 95 per cent.

In Fig. 9 is shown the local value of suction flow in each zone. The average values for each configuration of zones are shown on the curves for the lift coefficient 0.663. It will be seen that, for stabilization of the laminar boundary layer, over 95 per cent of the top surface requires a flow coefficient $C_Q = 4.9 \times 10^{-4}$ or about four times that computed by Ulrich for a flat plate. It must be pointed out that the porosity distribution chosen in this experimental research is not necessarily the optimum for minimum suction power requirements.

Another problem of boundary-layer control which this work has disclosed is the determination of the suction power required to overcome contour inaccuracies on the airfoil. Burrows, Braslow, and Tetervin[22] used a porous suction airfoil whose leading edge possessed considerable waviness. Because of the leading-edge waviness, suction was required even on the forward portion of the airfoil which, for a laminar section, would be expected to remain laminar without suction. Waviness on the leading edge evidently requires higher suction quantities than does a smooth leading edge. Pretsch[23] has shown the severe destabilizing influence of a number of waves in a flat plate. If these waves are in a region of rising pressure, the destabilizing effect on the laminar boundary layer is even more severe. It is evident then that, if suction power requirements are to be minimized, the waviness in the leading edge must of necessity be reduced below the usual production quality waviness.

Fig. 10 shows the pressure required for optimum boundary-layer control over the complete airfoil. It will be seen that at low lift coefficients the pressure required is less than the dynamic pressure. At higher lift coefficients, the internal wing pressure approaches $-1.4q$. This behavior would require a special pressure control for the suction source, be it a blower or an automatic suction source at the tip. Fig. 11 shows the distribution of suction along the chord. It may be found in later studies that the distribution of suction can be altered in order to economize on suction power. The precision with which the pressure control must be effected can be seen in Fig. 12. The suction pressure must be maintained within a region $1.28 < p/q < 1.44$.

The rapid movement of transition forward at suction pressures below $p/q = 1.28$ can be ascribed to destabili-

zation of the flow by local regions of outflow. But the reason for the advance of transition under too large a suction is not yet clearly delineated. Perhaps at high rates of flow into the holes there exists a cross flow that may be destabilizing. It may also be that behind the line of holes there is a reverse flow resulting in local separation. It may also be that the fabric on the wing is deflected excessively under the large suction pressures. Measurements are under way to resolve this behavior.

The reduction of wake drag resulting from the various configurations shown in Fig. 9 is displayed in Fig. 13. The profile drag was measured by the momentum loss method. The profile drag includes the drag of the bottom surface. For the suction region consisting of zones A+B+C+E+F, the total profile drag reduction including the power required for suction is seen to be 0.0045. The power required for suction was based on the ducting and blower efficiencies being 100 per cent. Losses through the rows of holes were, however, taken into account by the pressure loss through the fabric. Since the complete interior of the wing acts as a duct in this system and the flow velocities are extremely low, the losses due to ducting can be neglected. If blower efficiency of 80 per cent is taken, there will be available a total drag reduction of 51 per cent for only the top airfoil surface controlled by porous suction.

Conclusions

Concerning trailing-edge suction, using the slot recommended by Regenscheit, the following statements may be made:

(a) Free-flight measurements of amplification factor did not reach values as high as those claimed by Regenscheit.

(b) No drag reduction by laminar boundary-layer stabilization was found.

(c) Some drag reduction by prevention of turbulent boundary-layer separation at high lift coefficients was measured.

The investigation of suction sources showed the upper surface of a wing tip having a square trailing edge to be superior in suction pressures to a body of revolution.

A method of porous suction laminar boundary-layer stabilization has been developed which is simple to install and economical with regard to suction power. Experimental research on this method yielded the following salient points:

(a) It was impossible to establish a laminar boundary layer in a turbulent region by the use of normal suction quantities.

(b) A critical row spacing of 0.25 in. was found at $RN \leqq 4 \times 10^6$.

(c) Suction quantities four times those computed by Ulrich were necessary, though it may be possible to reduce these requirements.

(d) It was possible to apply too much suction and thereby move the transition forward.

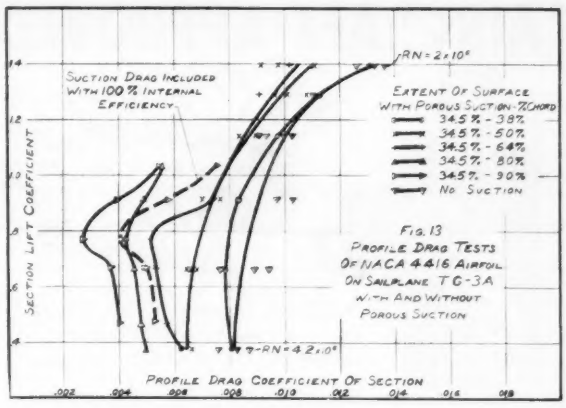

Fig. 13 Profile Drag Tests Of NACA 4416 Airfoil On Sailplane TG-3A With And Without Porous Suction

(e) The method of pricking holes into fabric is a convenient means for studying suction control under various distributions of local inflow.

(f) Considerable drag reductions were effected by this method of boundary-layer control.

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(*Continued on page 60*)

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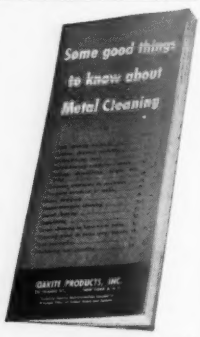

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Boundary-Layer Studies on a Sailplane

by August Raspet

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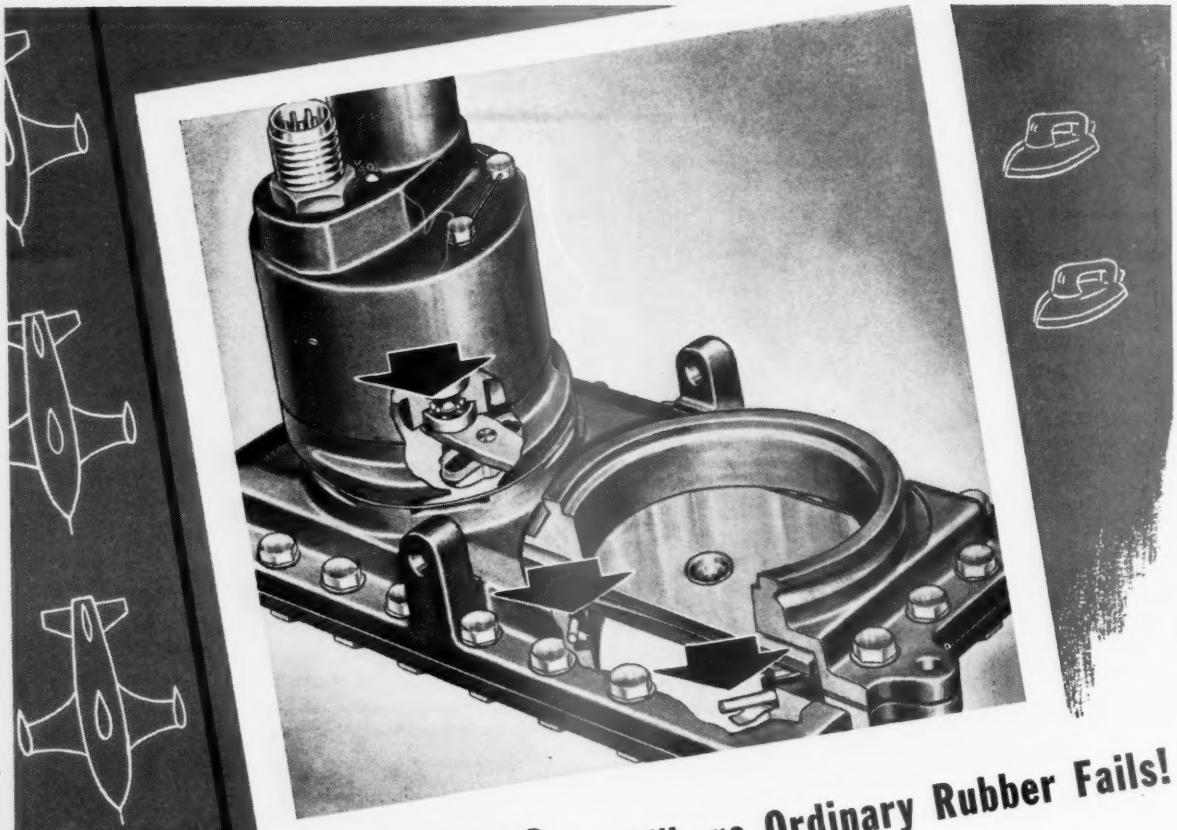

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Summaries of Current Papers Accepted for I.A.S. Publications

Creep Buckling of Columns

By

Charles Libove

Langley Aeronautical Laboratory

The creep of a slightly crooked H-section column carrying a constant load is studied theoretically. The material of the column is characterized by a strain-time relationship, under constant uniaxial stress, of the form $\epsilon = (\sigma/E) + Ae^{B\sigma}t^{K}$, where ϵ is the total strain, σ the constant stress, t the time, and E, A, B, and K material constants. This form was selected because it applies to at least two alloys—75S-T6 aluminum alloy at 600°F. and a low-alloy steel at 800° and 1,100°F.; however, the analysis is intended for any material having creep properties of the same form and for which the material constants are known. A strain-time relationship under variable uniaxial stress, necessary for the column analysis, is formulated from the constant-stress properties with the aid of Shanley's engineering hypotheses of creep.

The analysis leads to the conclusion that the lateral deflection approaches infinity—that is, the column collapses—in finite time. Results are given showing the maximum length of time the column can support a given load before it collapses and the growth of stresses, strains, and deflections prior to collapse.

Preprint No. 353

Visualization of Flow Fields by Use of a Tuft Grid Technique

By

John D. Bird

Langley Aeronautical Laboratory

A technique for obtaining a physical picture of the flow field behind a wing, combination of wings, or other airplane components is described wherein the action of a great number of tufts of uniform length, attached to a wire grid, are photographed from far downstream. This procedure yields, with a minimum of labor, an approximate vector plot of the flow field in a plane normal to the air stream. An examination of the data obtained from an application of this tuft grid technique to the study of the flow fields behind several low aspect ratio rectangular and delta wing arrangements indicates that analyses of such factors as trailing vortex strength and location and approximate downwash and sidewash angles over a large area around lifting surfaces and other aerodynamic forms may be satisfactorily conducted by this technique.

Preprint No. 351

Simplified Laminar Boundary-Layer Calculations for Bodies of Revolution and for Yawed Wings

By

Nicholas Rott and L. F. Crabtree

Cornell University

Since the introduction of momentum methods in boundary-layer calculations by von Kármán and Pohlhausen, many improvements have been proposed. An especially simple solution reduces the problem to a quadrature. Here, it is proposed to extend these methods to elementary three-dimensional cases and to compressible laminar boundary-layer calculations. For comparison, the corresponding problems for the turbulent boundary layer are also discussed briefly.

Preprint No. 359

On Weak Interaction of Strong Shock and Mach Waves Generated Downstream of the Shock

By

Boa-Teh Chu

The Johns Hopkins University

Analytical solutions are obtained for the flow behind an oblique shock wave produced by a wedge whose face is perturbed slightly from the straight line configuration. The solution is used to study the interaction of a shock wave and Mach waves generated downstream of the shock. It is found that Mach waves are reflected from the shock wave without change of sign but with reduced amplitude. The "reflection index" is given analytically. It approaches zero as the shock wave degenerates into a Mach wave and increases monotonically as the shock strength to a maximum of slightly less than unity. The interaction of the shock wave and the Mach waves generated by a small protuberance on the wedge surface produces an "almost similar" image on the shock wave with the longitudinal and transverse scales stretched in proper ratio. The shock wave also behaves like a porous elastic structure that deforms with a simple stress-strain relation. The solution is applied to calculate the pressure distribution on a "supersonic airfoil" at a large angle of attack. The extent of the downstream propagation of a small disturbance—e.g., that caused by a small hump on the wedge surface—is also estimated.

Preprint No. 357

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See page 61 for Preprints that are immediately available.

The Effect of Nonuniform Surface Temperature on the Transient Aerodynamic Heating of Thin-Skinned Bodies

By

A. E. Bryson and R. H. Edwards

Hughes Aircraft Company

A quasi-steady analysis is given of the transient forced-convection heating of bodies with thin metallic skins, where the boundary layer is laminar, taking into account the effect of the non-uniform surface-temperature distribution on the rate of heat transfer. Lighthill's approximate theory of heat transfer to a nonisothermal surface is used and leads to a formulation of the problem in terms of a partial integro-differential equation that is solved in closed form. The results are compared with previous analyses in which the theoretical heat-transfer coefficient for an isothermal surface is used, and it is shown that this latter approximation leads to results in fairly good agreement with the more exact solution. However, if heat-transfer coefficients are calculated from the more exact solution, they may

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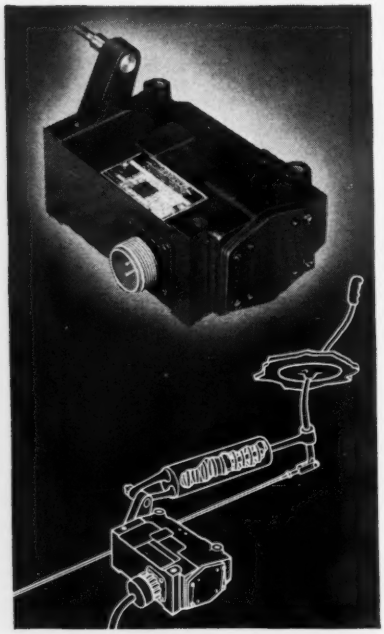

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differ greatly from the ones predicted by the isothermal surface theory. This indicates that caution should be exercised in interpreting experimental data obtained by the transient method from a nonisothermal surface where the boundary layer is laminar.

Preprint No. 356

Thermal Stress in Power-Producing Elements

By

A. S. Thompson
Oak Ridge National Laboratory

This paper considers the stresses in a material resulting from the flow of power through it when the density of power generated has a given distribution. From Hooke's law relating elastic stresses and strains, a general expression is derived for the order of magnitude of the thermal stress produced by a temperature difference in the material. The special case is studied of the stress in a heated cylindrical tube with a given distribution of power density and with heat flow through its inner surface. The stress in this cylindrical tube resulting from a power distribution in the form of a step function of the radius is determined.

It is shown that the expression for the maximum stress in the heated tube depends on three groupings of parameters—the first involving the properties of the heated material; the second, the average power density generated; and the third, geometry considerations. From these groupings of parameters, the following conclusions are drawn: (1) a material should be used having low values of the modulus of elasticity and the coefficient of thermal expansion and a high value of thermal conductivity; and (2) from geometry considerations the tubes should be of small diameter and the power should be generated in a thin layer of material directly at the cooled surface.

These thermal stresses are of importance since, in extreme cases, they are the cause of spalling (surface failure).

Analysis of Elastic Structures by Matrix Transformation with Special Regard to Semimonocoque Structures

By

Börje Langefors
Saab Aircraft Corporation

The system of equations for a redundant elastic structure is established by a routine procedure. The work is divided into separate steps, the first being the establishing of the *transformation matrix* by purely statical analysis. This first step is the only one where knowledge of structure analysis is demanded, all further steps be-

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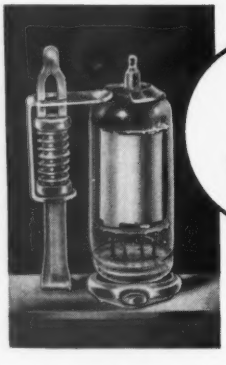

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ing simple matrix multiplications that can be performed by automatic means such as punched-card machines. The procedure is a modification of G. Kron's method for electric networks.

The structure can be analyzed by parts. Subsequent changes in member stiffnesses do not affect the transformation matrix, which can therefore be established once the geometry of the structure is specified. The rest of the work is a simple routine matter.

The system of equations obtained is reduced by matrix transformations of a similar kind.

The procedure for obtaining the system of equations is illustrated by a simple example.

Two Methods for Predicting Air Loads on a Wing in Accelated Motion

By

Holt Ashley, John Dugundji, and Donald O. Neilson

Massachusetts Institute of Technology

Aircraft taking off over a distance of 25 chordlengths or less are shown to experience an appreciable loss of lift due to unsteady flow effects. Two methods, the first based on Laplace-transformation solution of the integral equation and the second a simplified, approximate, iterative approach, are presented for evaluating the two-dimensional lift build-up during a maneuver involving changing forward speed and angle of attack. These schemes are applied to a number of examples, including Wagner's problem, which permit numerical comparisons. The effect of head wind on the unsteady lift deficiency is discussed.

Sherman M. Fairchild Publication Fund Papers

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AHS-1	Helicopter Flight Research at NACA, Langley—Jack P. Reeder.	$0.35	$0.75
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FF-5	Symposium on Standardization in Technical Information Services for Government Contractors.	$1.00	$1.00
FF-4	Finite Deflections of Curved Sandwich Plates and Sandwich Cylinders—F. K. Teichmann and Chi-Teh Wang.	$0.50	$0.85
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169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
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106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	$0.35	$0.50
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101	Introduction to Shock Wave Theory—J. G. Coffin.	$2.65	$3.50
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I.A.S. News

(*Continued from page 19*)

The Arnold Dwight Tuttle Award

An annual award for research achievement in aviation medicine was recently established to honor the memory of the late Col. Arnold Dwight Tuttle, U.S.A. (Ret.), M.I.A.S., who at one time was President of the Aero Medical Association and who for many years prior to his death on October 6, 1951, served as Medical Director of United Air Lines, Inc. The Arnold Dwight Tuttle Award, as it is called, was made possible by W. A. Patterson, President of United Air Lines.

The Arnold Dwight Tuttle Award was presented for the first time at the "Honors Night" Dinner during the twenty-third annual meeting of the Aero Medical Association. Its recipient was Edward H. Lambert, M.D., Acceleration Research Specialist, Mayo Clinic, Rochester, Minn.

This honor symbolizes, now and in the future, attainment of the "highest recognition" in the specialized field of aviation medicine "when it is bestowed [by the Aero Medical Association] upon that individual or group of individuals who has made the most outstanding contribution to the solution or partial solution of a challenging problem in aviation medicine by original research appropriately documented and published in the *Journal of Aviation Medicine*."

Aeronautical Engineering Catalog Available

The Eighth Annual Edition of the Aeronautical Engineering Catalog is now available. I.A.S. members may each receive a single copy gratis by simply sending a written request to the Director of Publications, Institute of the Aeronautical Sciences, 2 East 64th St., New York 21, N.Y., and giving their grade of membership and their company affiliation. Additional copies may be obtained at the purchase price of $7.50. It is also available to nonmembers for $7.50.

The Aeronautical Engineering Catalog is a must if you buy or sell aircraft or guided missile parts and equipment. Included features of the 1952 Aeronautical Engineering Catalog are: (1) a master file of company catalogs covering a wide range of aircraft products; (2) 2,400 aircraft and guided missile parts, materials, equipment, and accessories; (3) 40,000 manufacturer listings; and (4) names and current addresses of all principal manufacturers of aircraft products.

It is suggested that all persons who have need of this Catalog act immediately since the supply is limited.

Heat Transfer Symposium

A Symposium on Heat Transfer is being offered by the University of Michigan's College of Engineering during the forthcoming Summer Session, June 23 to August 15. The program, which was designed to meet the needs of advanced students, research engineers, and teachers in technical schools and colleges, will include lectures by outstanding engineering scientists and a number of special courses.

For information concerning the requirements for graduate credit or the summer courses, correspondence should be addressed to Prof. Harold M. Dorr, Director of the Summer Session, University of Michigan, Ann Arbor, Mich. For additional information about the Symposium on Heat Transfer, correspondence should be addressed to Prof. W. W. Hagerty, Department of Engineering Mechanics, College of Engineering, University of Michigan.

For those not wishing to work toward a degree, there are no special requirements except that the student have the necessary prerequisites to carry the work with profit.

Necrology

Ensign Richard C. Messerschmitt

Ensign Richard Christopher Messerschmitt, U.S.N., T.M.I.A.S., was killed in a bomber accident on September 13, 1951.

Ensign Messerschmitt was born in Trenton, N.J., on October 30, 1927, and attended the local public school system. He matriculated at Princeton University in July, 1945, and in February, 1949, was graduated with a B.S. degree in Aeronautical Engineering.

After his graduation, Ensign Messerschmitt remained at Princeton as a Research Assistant. At such, he compiled statistics and wrote a report analyzing the direct and indirect costs in the U.S. certificated air transport industry. He entered the Navy about a year or so before his death.

Major Robert A. Mortland

Major Robert Amos Mortland, U.S.A.F., T.M.I.A.S., was killed on November 19, 1951, in a B-47 bomber crash at Edwards Air Force Base, California.

Born in Clarion, Pa., on June 18, 1921, Major Mortland attended the local high school and in 1941 entered the United States Military Academy from which he was graduated in 1944. He underwent training as a pilot and at the time of his death was serving as an Air Force Test Pilot. Major Mortland also held a C.A.A. Commercial Pilot's Certificate with an instrument rating.

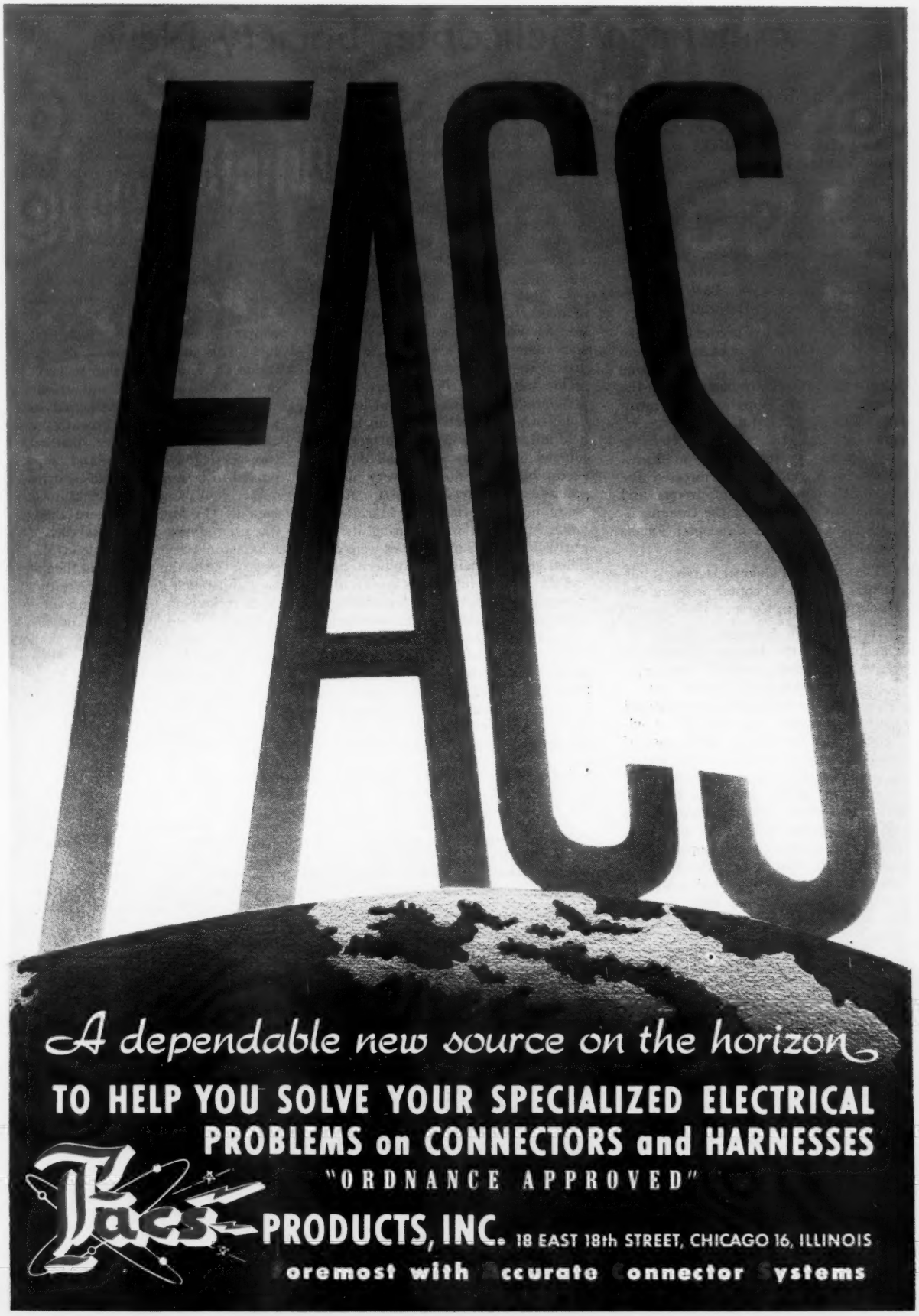
In 1949, Major Mortland was sent by the Air Force to Princeton University to work on his Master's degree in Aeronautical Engineering. He was granted this degree in June, 1951.

Eli Schwartz

Eli Schwartz, a Technical Member of the Institute, died on March 2. He was 28 years of age.

Born in Roselle, N.J., Mr. Schwartz attended the Townsend Harris High School in New York and subsequently the College of the City of New York. In June, 1947, he entered the University of Colorado and was graduated from there in the spring of 1949 with a B.S. degree in Aeronautical Engineering.

Immediately upon his graduation from the University of Colorado, Mr. Schwartz was employed as an Engineer-Pilot in the Flight Department of Consolidated Vultee Aircraft Corporation, San Diego. (He was the holder of the C.A.A. Commercial Pilot's Certificate #464,973.) Approximately 2 years prior to his death, he was forced into retirement after undergoing an operation for a brain tumor.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American Helicopter Society News

Joint A.H.S.–A.W.A. Meeting

A luncheon, cosponsored by the American Helicopter Society and the Aviation Writers Association, was held on March 12 at the National Press Club, Washington, D.C. It was attended by more than 150 members of the press, the military services, and the helicopter industry. Tom L. Wilson, Vice-President of the Southeastern Region, A.H.S., represented Bart Kelley, A.H.S. President, at the head tab'e.

Brigadier General Clayton C. Jerome, U.S.M.C., then Director of Aviation and Assistant Commandant of the Marine Corps for Air and now commanding the First Marine Air Wing in Korea, introduced the speaker, Lt. Col. George W. Herring, U.S.M.C. Colonel Herring, who had just returned from Korea where he organized and directed the first helicopter airlift of troops and equipment, is currently the Commanding Officer of Marine Helicopter Squadron One, Quantico, Va.

The subject of Colonel Herring's talk was the Marine helicopter program and its current role in Korea.

In his opening remarks, Colonel Herring outlined the background of helicopter employment in the Marine Corps. Under the National Security Act of 1947, the Marine Corps was charged with the primary responsibility of advancing the tactics and techniques of amphibious war. A means of dispersing shipping within an amphibious task force during atomic warfare became the first requirement. The problems created by this dispersal of shipping were ultimately answered by the troop-carrying helicopter in that it provides the amphibious task force with speed, mobility, and dispersion. Colonel Herring went on to cite the many advantages inherent in the use of the helicopter.

Before the end of 1946, Colonel Herring continued, the Marine Corps was authorized by the Chief of Naval Operations to commission one squadron for the purposes of evaluating and experimenting with the helicopter. It soon became apparent that there was a need for two definite and distinct types of rotary-wing squadrons—(1) the VMO or liaison squadron for evacuating the wounded, rescuing downed pilots, laying wire, and transporting staff officers, and (2) the HMR or transport-type squadron primarily for the movement of combat troops and secondly for the evacuation of the wounded. With the outbreak of hostilities in Korea, several squadrons of either type were authorized.

The remainder of Colonel Herring's talk was concerned with the first HMR unit, which he personally commissioned, and its overseas operations. The initial mission of this outfit in Korea was to evaluate the transport helicopter under combat conditions. Today, this unit is charged not only with cargo and troop lifts but also with wire laying, night evacuation of the wounded, etc.

Colonel Herring described the first of many such cargo lifts to which the unit has been assigned. "Our first mission came only a few hours after our arrival in the [First Marine] Division sector. It consisted of lifting desperately needed supplies to a front-line battalion whose objective was an enemy-held hill-top position. The attacks had jumped off at dawn, and all day the enemy bitterly contested every inch of ground he was forced to give up. About 2 p.m. in the afternoon the Marine battalion succeeded in capturing its objective. Supplies of all types were critically low; casualties had been high, and the enemy himself was known to be reorganizing and readying himself for an immediate counterattack in an effort to regain the lost ground. There were no roads within 2 miles of the newly won positions, and, even if there had been, there still existed a 2,500-ft. climb to the battle area. Hence, the transport helicopters were called into play. The squadron quickly arranged for a meeting with the battalion commander and together with him selected a site feasible for our helicopters to land upon and at the same time near enough to his companies to render the sorely needed logistical support.

"Execution of the operation called for shuttle movement on the part of the helicopters with a 2-min. interval between planes. Both aerial and artillery smoke were employed to screen the movement from enemy observation.

"During this operation, each helicopter carried a pay load of about 1,000 lbs. This on initial runs was placed inside the ships, but, due to excessive delay in both loading and unloading, subsequent loads were carried externally in cargo nets slung beneath the aircraft. This flying-crane method of transporting equipment and supplies proved to be a far more efficient means of accomplishing a logistical mission, such as this operation, and therefore was used almost exclusively thereafter. Pilots would release their loads on the edge of the landing point and then move over and touch down in the center for casualty loading. If no wounded were available for evacuation, a landing was never effected, and consequently little time was lost in clearing the landing site for the next 'copter.

"In one hour the operation was completed. Statistics of the lift revealed

(*A.H.S. News*
Continued on page 70)

A.H.S.-A.W.A. Luncheon: *Shown at the head table at the March 12 luncheon from left to right are: Capt. Frank Erickson, U.S.C.G., Special Assistant to Chief, Aviation Division, U.S. Coast Guard Headquarters; Tom L. Wilson, Vice-President—Southeastern Region, A.H.S.; Adm. D. C. Ramsey, U.S.N. (Ret.), President, Aircraft Industries Association; Brig. Gen. Clayton C. Jerome, U.S.M.C., then Director of Aviation and Assistant Commandant of the Marine Corps for Air; LeRoy Whitman, Deputy Area Governor, Aviation Writers Association; Lt. Col. George W. Herring, U.S.M.C., Commanding Officer, Marine Helicopter Squadron One, Quantico, Va.; Harvey Gaylord, Chairman, Helicopter Council, A.I.A., Vice-President, Bell Aircraft Corporation, and General Manager of Bell's Helicopter Division; Brig. Gen. John C. McQueen, U.S.M.C., Director of Public Information, U.S. Marine Corps.*

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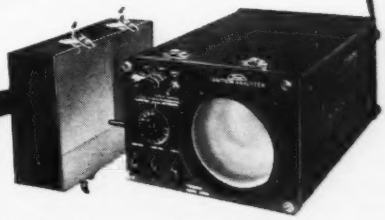

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A.H.S. News

(*Continued from page 68*)

some 17,000 lbs. of ammunition, rations, water, and medical supplies had been delivered to the attacking battalion, while 80 casualties were brought out on the return trips. The Division G-4 estimated without the helicopter some 24 hours would have been required to have accomplished the job. And more important yet, the battalion commander, whose troops we resupplied, stated he could not have successfully defended the position against the Communists' counterattacks that night without the materials brought in by HMR-161 some 2 hours before the attack started."

After Colonel Herring described a typical troop movement—this one involving the lifting of the Division reconnaissance company from the HMR-161 operation area to the top of a 2,000-ft. hill located on the extreme right flank of the Division sector—Colonel Herring gave the statistics of this lift. During the operation in question, 224 personnel members and 18,000 lbs. of cargo were lifted into the area. The overall time to complete the operation was 4 hours; the round trip took 28 min. In this instance, Colonel Herring stated, the Division felt that without the helicopter some 48 hours would have been required to complete the same task.

In his concluding remarks, Colonel Herring said: ". . . we have only scratched the surface in our transport helicopter operations. But we know where we are today; we know tomorrow's course, and I am confident that in the not-too-distant future we will revolutionize the tactic of amphibious warfare and in so doing eliminate the necessity of those costly beach assaults which were a requirement in so many instances in the last war."

News of Members

▸ **Haakon Aass** (T.M.) has been promoted from Lieutenant to Captain in the Royal Norwegian Air Force.

▸ **C. F. Baker** (F.), Chief Engineer, Hamilton Standard Division, United Aircraft Corporation, was elected Chairman of the Aircraft Industries Association's Propeller Technical Committee.

▸ **Dr. Louis H. Bauer** (M.), Editor-in-Chief, *Journal of Aviation Medicine*, received specially embroidered Flight Surgeons' wings at the twenty-third annual meeting of the Aero Medical Association, of which he is the founder. The presentation was made by Major Gen. Harry G. Armstrong, U.S.A.F. (M.C.), I.A.S. Fellow and Honorary Member, The Surgeon General, U.S.A.F.

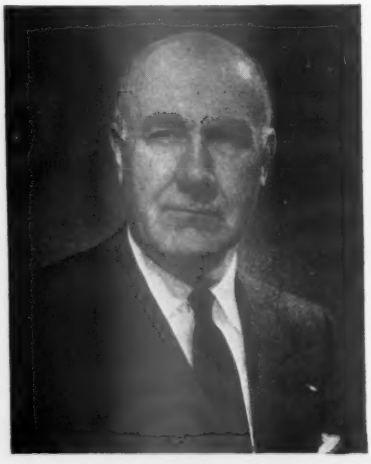
▸ **Colonel Robert J. Benford,** U.S.A.F. (M.C.) (A.F.), Air Surgeon, Air Research and Development Command, Baltimore, Md., was re-elected as a member of the Aero Medical Association's Executive Committee at the twenty-third annual meeting.

▸ **Colonel Paul Campbell,** U.S.A.F. (M.C.) (A.F.), Director of Research, U.S.A.F. School of Aviation Medicine, Randolph Air Force Base, Tex., has been elected to the Executive Council, Aero Medical Association, at the A.M.A.'s twenty-third annual meeting. Colonel Campbell's term expires in 1953.

▸ **L. A. Carter** (M.), Vice-President and General Manager, Santa Monica Division, Douglas Aircraft Company, Inc., has been placed in charge of the operation of Pacific Overseas Airlines' aircraft maintenance and overhaul base at Ontario, Calif.

NAMED TO NEW POST

Major General Edward M. Powers, U.S.A.F. (Ret.) (A.F.), has assumed the duties of General Manager of Wright Aeronautical Division, Curtiss-Wright Corporation. This new post is in addition to his earlier one as Vice-President of Engineering at Curtiss-Wright. General Powers, who joined the corporation in June, 1949, was elected to its Board of Directors last February.



▸ **F. Trubee Davison** (M.) resigned his post last April as Director of Personnel, Central Intelligence Agency, and as Assistant to its Director, Lt. Gen. Walter Bedell Smith. Mr. Davison is President-Emeritus of the American Museum of Natural History, New York City.

▸ **J. Dean Ellis** (M.), Consulting Engineer and Chief, Manufacturing Methods Bureau, Headquarters, Air Materiel Command, Wright-Patterson Air Force Base, Ohio, has completed 40 years in aviation as of June 10. For about 25 years, he has been a Consultant. His Research and Development Institute has been in existence for over 20 years.

▸ **Stanley Hiller, Jr.** (T.M.), President, Hiller Helicopters, was selected as one of the Ten Outstanding Young Men of 1951. The presentation of the accompanying Distinguished Service Award was made at the United States Junior Chamber of Commerce banquet held in Dayton, Ohio, on January 19. Mr. Hiller was originally nominated for this award by the San Francisco Junior Chamber of Commerce.

▸ **C. F. Horne** (H.M.), Administrator, Civil Aeronautics Administration, was made an Honorary Member of the Aero Medical Association.

▸ **Grover Loening,** I.A.S. Benefactor and Fellow, Consultant on Aircraft, has announced the reactivation this year of the Loening Intercollegiate Flying Trophy under the administration of the National Aeronautic Association. The awarding of this trophy, which was inaugurated in 1929 and last presented in 1940, will be based on the activities and accomplishments of college or university flying clubs. The winners will be determined by a committee appointed annually by the N.A.A. to evaluate the flying club activity reports submitted.

▸ **Dr. W. Randolph Lovelace, II** (F.) has resigned as Chairman, Armed Forces Medical Policy Council, to return to private practice. Dr. Lovelace is Head of the Section on Surgery, Lovelace Clinic, and is Director of the Lovelace Foundation for Medical Education and Research, Albuquerque, N.M.

▸ **John L. Senior, Jr.** (M.), Chairman of the Board, New York Airways, Inc., issued a statement that helicopter service in the New York metropolitan area, for which his company has been authorized, should get underway late this year. Passenger service, he said, will follow as speedily as necessary aircraft and facilities become available. The Civil Aeronautics Board granted New York Airways an Air Carrier Operating Certificate on March 13 for helicopter mail and passenger service

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▸ **C. R. Smith** (A.M.), President, American Airlines System, heads the Executive Committee that has been given full authority to act for the full 19-man National Air Transport Committee, established to handle air-line problems in the New York-Newark area.

▸ **Francis S. Stewart** (M.), Industrial Chemical Engineer, has opened a consulting and research service on plastics. Offices and laboratory are located at 10819 Venice Blvd., Los Angeles 34, Calif.

▸ **Dr. Thomas H. Sutherland** (M.), of Marion, Ohio, was re-elected Secretary-Treasurer and Business Manager of the Aero Medical Association.

▸ **B. R. Teree** (A.F.), Chief Engineer, Aircraft Division, The Weatherhead Company, has been elected an Associate Fellow of Britain's Royal Aeronautical Society.

▸ **Dr. Theodore Theodorsen** (F.), formerly Chief, Division of Physics, N.A.C.A., and since 1947 under contract with the Brazilian Government at Rio de Janeiro, has returned to the States and is now Contract Administrator, Air Research and Development Command Headquarters, Baltimore.

▸ **Dr. Theodore von Kármán** (H.F.), who has been serving as Chairman of the Scientific Advisory Board, U.S.A.F., was named Chairman of the recently organized Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization.

▸ **Dr. Edward P. Warner,** I.A.S. Honorary Fellow and Benefactor, President of the Council, International Civil Aviation Organization, was awarded the Gold Medal by the Fédération Aéronautique Internationale. The F.A.I. Gold Medal was given to Dr. Warner for his meritorious contributions to the progress and development of the United States and world civil aviation.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

William B. Anderson (M.), Assistant to the Executive Vice-President, Westinghouse Electric Corporation. Formerly, Manager, Aviation Gas Turbine Division, Westinghouse.

NEW POSITION

Alan F. Broz (T.M.) was named Director of Research and Development for Standard-Thomson Corporation. Prior to this appointment, Mr. Broz has been a member of Robbins-Broz Company, Chief Engineer for Crosby Research Foundation, and Chief Project Engineer for the Pacific Division of Bendix Aviation, Inc.

Harold Andrews (T.M.), Assistant Research Mechanical Engineer, Cornell Aeronautical Laboratory, Inc. Formerly, Aviation Electronics Technician—1st Class, U.S.N.R.

First Lieutenant R. G. Averill, U.S.A.F. (A.M.), Transportation Officer for Air—Navigator, 6611th M. & S. Sq., A.P.O. #858, c/o P.M., New York. Formerly, Director, Visioneering in Management, R. G. Averill Associates.

Second Lieutenant Weaver E. Barnett, U.S.M.C. (T.M.), Co. "A," 1st Trng. Bn., 13th S.B.C., Camp Barrett, Quantico, Va. Formerly, Junior Engineer, Ordnance Aerophysics Laboratory, Consolidated Vultee Aircraft Corporation.

Paul S. Bauer (M.), now Commander, U.S.N., on Extended Active Duty.

Miss Beverly Beane (T.M.), Aerodynamicist, Santa Monica Plant, Douglas Aircraft Company, Inc. Formerly, Analytical Engineer in Aerodynamics Research, Massachusetts Institute of Technology.

Emric W. Bergere (M.), Chief of Production Methods, Long Beach Plant, Douglas Aircraft Company, Inc. Formerly, Chief of Production Engineering, Long Beach Plant, Douglas.

Ramesh Bijoor (T.M.), Engineer, Canadair, Ltd. Formerly, Student.

Major Eugene A. Blue, U.S.A.F. (T.M.), now Research and Development Officer, Armed Forces Special Weapons Project, Kirtland Air Force Base, N.M.

J. R. Boyd (M.), now Departmental Head, Paxton Engineering Company.

Charles Buhman, Jr. (T.M.), Lead Man on B-47B Controls and Design Engineer "B," Georgia Division, Lockheed Aircraft Corporation. Formerly, Layout Draftsman, McDonnell Aircraft Corporation.

Charles Christenson (M.), Preliminary Design Engineer, Lockheed Aircraft Corporation. Formerly, Associate Professor of Aircraft Design, Instituto Technologico de Aeronautica, Brazil.

James A. Cline (T.M.), Pilot, American Airlines System, LaGuardia Field, New York. Formerly, Student.

Wilson Dale Cooper (T.M.), Service School Instructor, Lincoln-Mercury Division, Ford Motor Company. Formerly, Field Manager, Lincoln-Mercury Division, Ford.

John Cory (T.M.), Special Products Engineer, Ford Motor Company of Canada. Formerly, Design Engineer, A. V. Roe Canada, Ltd.

Paul A. Dennis (A.F.), Engineer, William Miller Corporation. Formerly, Chief, Engineering Laboratory, El Segundo Plant, Douglas Aircraft Company, Inc.

Donald L. Ellenberger (T.M.), Designer, General Electric Company, Fort Wayne, Ind. Formerly, Student.

J. C. Fetters (A.F.), Chief Engineer of Turboprop and Other Power Turbine Design and Development, Allison Division, General Motors Corporation. Formerly, Chief Turbine Engineer, Allison Division, G.M.C.

Daniel J. Fink (T.M.), Research Engineer, Allied Research Associates, Inc. Formerly, Group Leader, Aircraft Dynamics and Flutter, Bell Aircraft Corporation.

James B. Fleming, Jr. (T.M.), Engineering Designer "B" and Armament Liaison Engineer, El Segundo Plant, Douglas Aircraft Company, Inc. Formerly, Engineering Draftsman "A" and Armament Liaison Engineer, El Segundo Plant, Douglas.

Kenneth M. Foreman (T.M.), Senior Test Engineer, Wright Aeronautical Division, Curtiss-Wright Corporation. Formerly, Research Engineer, Eclipse-Pioneer Division, Bendix Aviation Corporation.

D. A. Francis (M.), Vice-President, Micro Balancing, Inc. Formerly, with Government Sales Department, Sperry Gyroscope Company.

William M. Fromme (T.M.), Aerodynamicist, Northrop Aircraft, Inc. Formerly, Aeronautical Engineer, The RAND Corporation.

James M. Gillespie (M.), Manager, Export Department, AiResearch Manufacturing Company, Division of The Garrett Corporation. Formerly, Assistant and Technical Adviser to the President, AiResearch.

Carroll G. Gordon (M.), now Design Engineer "A," Fletcher Aviation Corporation.

Leslie D. Gould (A.M.), now Inspector, Procurement Division, Republic Aviation Corporation.

Malcolm S. Harned (M.), Chief of Aerodynamics, Marquardt Aircraft Company. Formerly, Project Engineer, Marquardt.

Lieutenant Paul E. Herbert (T.M.), now with 730th Bomb. Sqdn. (L.), A.P.O. 970, c/o P.M., San Francisco.

Robert F. Hunter (T.M.), Sales Engineer, Shafer Bearing Corporation. Formerly, Engineer, Douglas Aircraft Company, Inc.

C. R. Irvine (M.), Assistant to Vice-President—Engineering of Guided Missile Research and Development, Consolidated Vultee Aircraft Corporation. Formerly, Chief Engineer, Guided Missile Division, Convair.

K. R. Jackman (A.F.), Chief of Test Laboratories, Guided Missile Division, Consolidated Vultee Aircraft Corporation. Formerly, Chief of Test Laboratories, Convair, San Diego.

Ervin T. Kautt (T.M.), Design Engineer, Tri-State Design Service. Formerly, Stress Analyst, North American Aviation, Inc.

Barney Luther Lewis (T.M.), Engineering Draftsman "A," Hayes Aircraft Corporation. Formerly, Junior Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

Dr. Richard H. Lloyd (M.), Aeronautical Research Engineer, Cornell Aeronautical Laboratory, Inc. Formerly, Senior Scientist, Propulsion Systems Study, Experiment Incorporated.

Kenneth Mann (M.), Staff Engineer, Research and Development, Hiller Helicopters. Formerly, Structures Engineer, Rotor Group, Piasecki Helicopter Corporation.

K. G. McCallum (M.), Stress Analyst, Scottish Aviation, Ltd., Scotland. Formerly, Stress Analyst, Vickers-Armstrongs, Ltd., England.

Robert G. Melrose (M.), General Manager, Guided Missile Division, Republic Aviation Corporation. Formerly, Director, Technical Liaison Division, Republic.

William M. Menco (T.M.), with United Aircraft Service Corporation, Edwards Air Force Base, Calif. Formerly, Junior Engineer—Aerodynamics, Chance Vought Aircraft Division, United Aircraft Corporation.

Frank F. Miller (T.M.), now Dispatch Clerk, United Air Lines, Inc.

Arthur M. G. Moody (M.), Senior Development Engineer, Trame Company. Formerly, Chief Engineer, Blower Division, Elliott Company.

David A. Mosher (T.M.), Product Engineer, Thomas Hydraulic Speed Controls, Inc.

Second Lieutenant Harold M. Moss (T.M.), Headquarters, Air Research and Development Command, P.O. Box 1395, Baltimore Md. Formerly, Instructor and Graduate Student, Rensselaer Polytechnic Institute.

Joseph J. Nowak (T.M.), Wind Tunnel Department, Cornell Aeronautical Laboratory, Inc. Formerly, Test Engineer, Rocket Development Section, Bell Aircraft Corporation.

James C. O'Hara (T.M.), Wind Tunnel Department, Operations Section, Cornell Aeronautical Laboratories, Inc. Formerly, Engineering Trainee on Assignment to Cornell Aeronautical Laboratories, ARO, Inc.

S. Allen Oviatt (M.), Manager of Sales Engineering, Kennametal Inc. Formerly, Account Executive, Gardner Displays Company.

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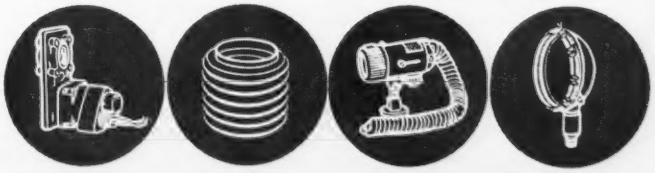

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James Gordon Page (T.M.), Draftsman, North American Aviation, Inc. Formerly, Intelligence Section, 728th Bombardment Sq., U.S.A.F., A.P.O., 970, c/o P.M., San Francisco.

Thomas M. Perkins (T.M.), Second Lieutenant, U.S.A.F.R., on Extended Active Duty. Formerly, GS#5, Assistant Engineer, Sub-Sonic Project Unit, Wind Tunnel Branch, Air Development Command, Wright-Patterson Air Force Base, Ohio.

Donald H. Price (T.M.), now Senior Aerodynamicist, Raytheon Manufacturing Company.

J. Louis Reynolds (M.), Director of Customer Relations, Marquardt Aircraft Company. Formerly, Assistant to the President, Jack & Heintz, Inc.

Edward W. Rice, Jr. (T.M.), Pilot, United Air Lines, Inc. Formerly, Administrative Assistant, Research and Development Laboratories, Hughes Aircraft Company.

Robert E. Robischon (A.M.), Director, Division of State Publicity, New York State Department of Commerce. Formerly, with Esso Export Corporation.

Dr. Maurice Rothman (M.), Senior Lecturer in Mathematics, The Northern Polytechnic, London, England Formerly, Lecturer in Mathematics, The Royal Technical College, Glasgow, Scotland.

Captain John R. Ruhsenberger, U.S.N. (M.), Deputy Commander, Iceland Defense, A.P.O. 81, c/o P.M., New York. Formerly, Commanding Officer and Director, Special Devices Center, Office of Naval Research, Port Washington, N.Y.

Dr. Raymond John Seeger (A.F.), Staff Member, Division of Mathematical, Physical and Engineering Sciences, National Science Foundation. Formerly, Chief, Aeroballistics Research Department, Naval Ordnance Laboratory, White Oak, Md.

John L. Senior, Jr. (M.), Chairman of the Board, New York Airways, Inc. Formerly, President, New York Airways.

J. A. Slonim (M.), now President, Stamford Electronics Company.

Frederick O. Smetana (T.M.), now Teaching Fellow and Candidate for M.S. degree in Aeronautical Engineering, North Carolina State College.

Mel Swerdling (T.M.), Design Engineer, Lockheed Aircraft Corporation. Formerly, Aircraft Designer "A," Republic Aviation Corporation.

Kelsey Walker, Jr. (T.M.), Missile Aerodynamics Engineer, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Research and Teaching Assistant, Graduate Student, Massachusetts Institute of Technology.

Robert K. Wead (M.), Chief Production Engineer, Marquardt Aircraft Company. Formerly, Project Engineer, Marquardt.

Captain Wyvel T. Williams, Jr. (T.M.), Recalled to Extended Active Duty, U.S. Marine Air Corps. Formerly, Service Liaison Engineer, Chance Vought Aircraft Division, United Aircraft Corporation.

Corporate Member News

• **Aerojet Engineering Corporation** . . . It has been reported that the Aerojet has joined two Italian firms in establishing Compagnia Generale Italjet for the purpose of manufacturing rockets in Italy and selling them to friendly nations of western Europe. The two Italian firms concerned in this three-way deal are: Fiat and Industrie Meridionali Munizioni Affini (IMMA). Headquarters of the newly formed Italjet are in Rome, Italy.

• **AiResearch Manufacturing Company, Division of The Garrett Corporation** . . . The Customer Service Department has been moved to its own quarters in a 33,000-sq.ft. building adjacent to the Los Angeles International Airport. Space is provided here for service stores.

• **Al-Fin Division, Fairchild Engine and Airplane Corporation** . . . Two American producers of aluminum castings, Aluminum Company of America and Bohn Aluminum and Brass Corporation, have been licensed to use the patented Al-Fin process for the molecular bonding of aluminum to iron or steel.

• **Allis-Chalmers Manufacturing Company** . . . An Apparatus Department was recently established to effect a more complete integration of related lines of products. Under this new setup, the Texrope Drive and Pump departments have become sections of the Apparatus Department . . . The factory now under construction at Terre Haute, Ind., is scheduled for completion in 1952 and will be used for the production of compressors for the Wright Sapphire turbojet engine.

NEW POSITION

Sherman S. Graves, A.M.I.A.S., has been appointed General Manager of the new Helicopter Division at Cessna Aircraft Company. This division was formed as a result of the recent purchase by Cessna of the Seibel Helicopter Company. Mr. Graves, who has been with Cessna for more than 16 years, was formerly Chief Inspector of the company. He has held an active pilot's license since 1936.

• **Aluminum Company of America** . . . A project involving the expenditure of $1,217,000 for the modernization and revision of Alcoa's ingot casting facilities at Vancouver, Wash., has been announced. This is the forerunner of a plan to extend and diversify the fabrication of primary aluminum at Vancouver.

• **American Airlines System** . . . Last April 4 was the twenty-fifth anniversary of the first New York-to-Boston scheduled passenger service. This particular flight, which took off at twilight on April 4, 1927, and which is believed by American to have been the first night flight with passengers in the United States, was operated by American's predecessor, Colonial Air Transport, Inc.

• **Bell Aircraft Corporation** . . . Licensing agreements have been completed with three European companies for the manufacture of Bell Model 47D-1 commercial and military helicopters and helicopter parts. Two of the companies have been licensed to manufacture the helicopter, *viz.*, Aersilta Societa Per Azioni, of Milan, Italy, and Société National de Constructions Aéronautiques du Nord (SNCAN), of Paris, France. The third firm, Hordern-Richmond Ltd., of Haddenham Buchs, England, has been licensed to manufacture rotor blades for this helicopter.

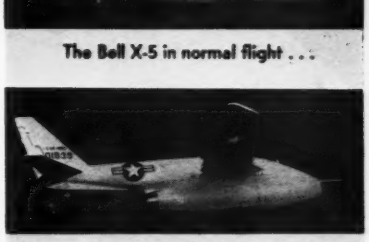
• **Boeing Airplane Company** . . . Recent research at Boeing relative to machining aircraft parts with close tolerances has resulted in evolving a method whereby cutters can be formed from carbide for use on helical tool bodies. The new helical carbide cutter is said to enable standard milling machines to shape certain structural parts more accurately and almost three times faster than other cutters. Other advantages claimed for this new cutting tool design are that it requires less power to operate and that it has a longer service life between removals for sharpening. It is estimated by Boeing engineers that the helical carbide cutter will retain its sharp cutting edge three times as long as a straight carbide cutter and nine times as long as a helical high-speed steel cutter. . . . A lightweight gas-turbine engine is now being manufactured on a production basis for the U.S. Navy. In order to handle the design, production, and marketing of this 200-lb., 175-hp. engine, a new division has been established. Tests were begun some months ago with the installation of this engine in a Navy personnel boat, a Kaman helicopter, and a Kenworth heavy-duty truck; present plants call for its use in a light aircraft, a military vehicle, a generator, and a ground-power unit for aircraft. . . The commercial production and marketing program for electronic computers is being expanded. Boeing is continuing with the production of its basic low-cost computer; however, the company has announced its intention of supplying associated components, such as servo-multiplying units, function generators, and prepatching system, to extend the versatility of this unit. The computer, which operates on the simulation principle, is designed to solve a wide range of everyday industrial and research dynamics problems comprising both linear and nonlinear systems.

• **Canadair, Ltd** . . . Rear Adm. Lawrence B. Richardson, U.S.N. (Ret.), F.I.A.S., who was recently elected a Director and Senior Vice-President of Electric Boat Company and a Director of Canadair, was named to the new office of Canadair's Vice-Chairman and a member of its Executive Committee. John Jay Hopkins, Chairman of the Board and President of Electric Boat and Chairman of Canadair's Board, has been made Managing Director of Canadair. A third change involving Electric Boat and its subsidiary, Canadair, is the election of J. Goeffrey Notman as Canadair's President and General Manager. Mr. Notman, who was Executive Vice-President of Canadair, was recently

THE X-5 PERFORMS

Bell Aircraft Corporation's X-5, the third of America's experimental planes, demonstrates its ability to change its sweepback angle during flight. The mechanism that governs this action compensates simultaneously for the resulting shift in the center of gravity.

The Bell X-5 in normal flight . . .



The X-5 begins to sweep its wings.

Wings are moved back 50 per cent.

Sweep requires only 30 seconds.

Wings now in fully swept position.

elected a Director and Senior Vice-President of Electric Boat.

• **The Cleveland Pneumatic Tool Company** . . . Lawrence E. Green, Chairman of Board of Directors, died suddenly at his office in Boston, Mass., on March 27. Mr. Green was a partner in the law firm of Hale and Dorr, Boston.

• **Consolidated Vultee Aircraft Corporation** . . . Type Certificate No. 6A6 has been issued to Convair and authorizes the issuance of airworthiness certificates to air lines for operating the Convair-Liner 340 up to a gross weight of 46,725 lbs. This is an increase of 1,725 lbs. over the weight specifications originally announced for the 44-passenger 340. . . Three new district offices have been opened recently at Detroit, Los Angeles, and Newark, N.J. . . V. C. Schorlemmer has resigned his position as corporation Secretary and Treasurer to become Assistant to the Vice-President and General Manager, A. P. Fontaine. L. W. Miller was elected Acting Treasurer; Edmund Burke, who has been Assistant Secretary and Treasurer, was elected Secretary and will continue as Acting Treasurer.

• **Douglas Aircraft Company, Inc.** . . . The DC-6B has been certified for a gross take-off weight of 107,000 lbs. The gross weight previously approved by the C.A.A. was 100,000 lbs. Virtually all of the increased weight will be used in added fuel to increase the aircraft's range . . . The Aircraft Maintenance and Overhaul Base of Pacific Overseas Airlines was transferred in April to the Ontario, Calif., International Airport. There, in a leased facility, Douglas is performing heavy maintenance work on the R6D Liftmaster (DC-6 type) transports for the U.S. Navy and on other large Douglas aircraft.

• **Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation** . . . An R-4Q, the Navy version of the C-119 Flying Boxcar, successfully passed a structural flight-test demonstration at the Naval Air Station, Patuxent, Md., on April 4. The R-4Q had been modified to exceed by a considerable margin the U.S. Navy and Air Force specification requirements for cargo aircraft. Structural changes included the addition of ventral fins to the tail and changing the spring tab of the rudder control system.

• **General Electric Company** . . . A quartz and steel probing instrument, known as a flame detector, is being used by G-E's Aircraft Gas Turbine Division engineers to test the various sections of the tailcone of a jet engine while that engine is operating, so that possible faulty combustion areas and unnecessary flame leakage can be pinpointed. The flame detector can also be used to locate flame leakage in passageways to the jet-engine turbine buckets. Developed by the company's General Engineering Laboratory, the instrument combines a 4-ft. length of metal-sheathed quartz filament with a photoelectric converter and amplifier. A heat shield and air-cooling system protects the amplifier against the intense heat produced by the engine. In operation, this instrument picks up the light waves within the area exposed to the detector and converts them into an electric current that by amplification can be seen by observers either on an indicating instrument or on a graph recorder connected to the amplifier tube. . . A new general-purpose hermetically sealed relay (CR2791G) for use in aircraft, shipboard, and portable land-based electrical systems and electronic equipment was recently announced by G-E. This relay was designed to meet or better the provisions of the Joint Military Service Specifications for Relays (MIL-R-6106) and to conform with the Air Force-Navy Aeronautical Standard AN-3304. Based on tests in the company laboratories, G-E engineers say that this new device offers increased reliability and from two to six times longer life than existing equipments. The new relay is a 4-pole double-throw type, with a contact rating of 3 amp., 28 volts d.c. or 115 volts a.c. It is claimed that the relay will withstand instantaneous voltage surges up to 1,500 volts without failure. Full details will be found in G-E's Bulletin GEA-5729. . . Scholarships, fellowships, and grants amounting to $370,000 are being offered by G-E for the 1952–1953 academic year. This amount represents a 60 per cent increase over that offered for the 1951–1952 school year.

• **Grumman Aircraft Engineering Corporation** . . . The existence of two new aircraft has been confirmed in Grumman's 1951 annual report. One of them is the XF10F, "a completely new and advanced type of fighter plane"; the other is the XS2F, "a new design airplane for anti-submarine warfare."

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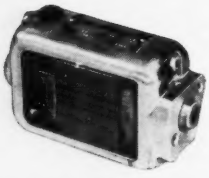
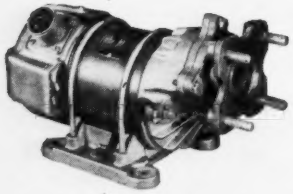


Motor having substantial power output for computing machines and other types of motor-driven office equipment.



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• **Hamilton Standard Division, United Aircraft Corporation** . . . A recently announced new type of high-speed pump for aircraft hydraulic systems is said to be one of the smallest, lightest, and most powerful yet developed for this purpose. This pump is already in limited production. In operation, it is driven by the aircraft engine from which it absorbs 36 hp. This power is then transferred to the hydraulic system by circulating oil at rates of up to 25 gals. per min. and pressures of 3,000 lbs. per sq.in. The pump operates at speeds up to 8,250 r.p.m.

• **The International Nickel Company, Inc.** . . . A 20-page bulletin, "Iron-Nickel Alloys for Magnetic Purposes (20 to 40% Nickel)," has been released through International Nickel's Department EZ, New York 5, N.Y. The bulletin discusses the more important "magnetically soft" alloys, giving tables and graphs, trade names, sources of supply, typical applications, etc.

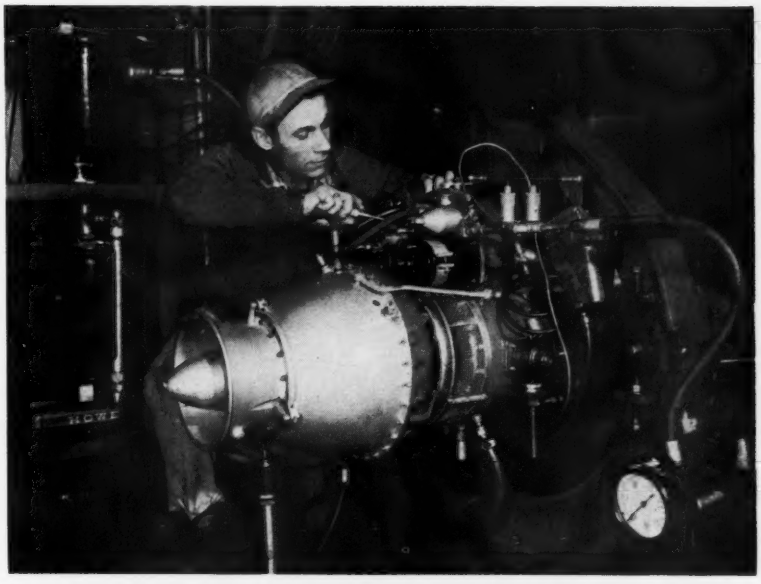
• **The M. W. Kellogg Company** . . . The Brazilian refinery of Conselho Nacional do Petroleo, completed in 1950 at Mataripe, State of Bahia, is now undergoing expansion, according to a recent announcement by Kellogg, designers of both the original and the new facilities at this refinery. When this new construction under the supervision of Kellogg Pan American Corporation is completed, the capacity of the present 2,500-barrel-per-day combination thermal refinery will be doubled. . . A new technical bulletin on the properties of Kel-F oils, waxes, and greases is now available. Copies of Technical Bulletin #5-1-52 may be had by writing the Chemical Manufacturing Division of Kellogg at P.O. Box 469, Jersey City 3, N.J.

• **Kollsman Instrument Corporation** . . . Rear Admiral Clyde W. Smith, U.S.N. (Ret.), was named Assistant to the President of Kollsman. Prior to Admiral Smith's retirement from the Navy in 1947, he served as Director, Airborne Equipment Division in charge of materials and equipment, Bureau of Aeronautics, U.S. Navy.

• **The Glenn L. Martin Company** . . . According to the recent annual report, the company is developing new and advanced versions of the B-57A Canberra and is working on a "highly advanced" air-to-air missile that is due for its first flight this year and on an electronics air-defense project for the Army Signal Corps.

• **Minneapolis-Honeywell Regulator Company** . . . A recently announced tiny aircraft servomechanism that is about the size and shape of a couple of packs of cigarettes and weighs approximately a pound was designed to solve the difficult problem of moving various control surfaces on supersonic and other high-speed aircraft. This device, known technically as the SS hydraulic servo, is able to transform extremely weak signals into powerful mechanical energy and to respond to more than 100 signals a second. In its development, Honeywell engineers utilized a basic principle that was originated at Massachusetts Institute of Technology.

• **North American Aviation, Inc.** . . . The first Navy AJ-2P carrier-based photo reconnaissance bomber built by the Colum-



OREDON ON STRATOS TEST STAND

The Oredon gas turbine engine, developed and built by Société Turbomeca for the operation of accessories such as large generators or alternators, is being modified by the Stratos Division of Fairchild Engine and Airplane Corporation to fit American requirements. It will be produced by Stratos under license from the French engine company. The Oredon is rated at 140 shaft hp. for continuous operation and at 160 shaft hp. for short-interval operation; its speed control system holds the r.p.m.'s within a plus or minus 0.4 per cent. The Oredon's specifications include: overall length, 31.7 in.; diameter, 20.5 in.; weight, 185 lbs.; specific fuel consumption, 1.04 lbs. per shaft hp. per hour; and normal period between overhauls, 500 hours.

THE FIGHTER-BOMBER COMBO, THE F-84F

Republic Aviation Corporation's F-84F Thunderjet, due to roll off the assembly line later this year, is said to outperform the F-84E in range, speed, and altitude, as well as in the amount of armament carried. Standard fixed armament consists of six M-3 type 0.50-cal. machine guns—four in the nose and one in either wing. As a long-range fighter, the F-84F can carry two 450-gal. fuel tanks (upper left). Some of its standard operational armament loads are also shown in this photograph. They include: 24 5-in. HVAR rockets (in front of plane), or four 1,000-lb. bombs (right foreground), or a mixture of fuel and armament, such as two 1,000-lb. bombs and two 230-gal. fuel tanks (left foreground). Other types of armament, such as napalm tanks (above), smoke tanks, or antipersonnel bombs, can be carried with above combinations of armament or fuel. A redesigned nose section converts this fighter-bomber into a photo reconnaissance version. The F-84F is powered by the Wright J-65 Sapphire turbojet engine.

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bus Division made its first test flight last March. The flight lasted 29 min. The 25-ton AJ-2P Savage is powered by two Pratt & Whitney R-2800 reciprocating engines and one Allison J-33 turbojet engine. It carries a crew of three—pilot, bombardier-navigator, and engineer-specialist—at speeds approximating 425 m.p.h. . . . The first model of the F-86F, now rolling off the production lines in both the Los Angeles and Columbus, Ohio, plants, was delivered to the U.S. Air Force on March 28. This improved version of the Sabre is powered by the General Electric J47-GE-27 jet engine, which has a thrust rating in excess of 5,800 lbs. The "F" will fly more than 650 m.p.h., has a combat radius of over 600 miles, and has a maximum service ceiling of better than 45,000 ft. It carries six 0.50-cal. machine guns. . . The production of the F-86H, the fifth in the Sabre production series, will reportedly get underway sometime this year in Los Angeles. The "H" model is said to follow the same general lines as the F-86E, although slightly larger. The earlier production models of the Sabre are the F-86A (now out of production), the F-86D, the F-86E, and the F-86F.

• **Northrop Aircraft, Inc., and Bendix Aviation Corporation . . .** The exclusive rights for the manufacture and marketing of "Maddida," the electronic computer developed by Northrop, have been sold for an undisclosed sum to Bendix. The sale includes all capital assets of Northrop's computer manufacturing department, including machinery, electronic equipment, and engineering data, as well as the manufacturing and sales rights to "Maddida." Under the terms of the transaction, Bendix is given full authority to use the trade names of "Dida" and "Maddida." Under the agreement, Northrop retains patent rights and, in addition to a cash sum, is to receive royalties on its invention.

• **Northrop Aircraft, Inc., and The Dow Chemical Company . . .** Northrop process engineers are said to have developed a method that makes feasible the eliminating of all of the ribs and 80 per cent of the rivets now used in complete aircraft control surfaces. This new method uses Styrofoam, a hard plastic foam developed by Dow Chemical, as an inner "filler" for control surfaces, which, by filling in the voids within the control surfaces, is said to eliminate vibration. Process engineers at Northrop have developed a metal-plastic adhesive, which is a modification of existing synthetic resins, for bonding Styrofoam to sheet metal. This adhesive, now being patented by Northrop, is applied by either brush or spray to all mating surfaces which are then sealed by pressure contact. The engineers working on this project believe that the "continuous bonding" of control surfaces that use Styrofoam makes them considerably stronger than ribbed surfaces of comparable size. Northrop engineers state that by use of the patented Northrop adhesive, Dow Chemical's Styrofoam may be successfully used with wood, glass laminate, fabric, aluminum, or metal.

• **Pan American World Airways, Inc.** . . . Boeing Stratocruiser service was inaugurated on April 2 between New Zealand and the United States via Fiji and Hawaii.

On the first of the following month, Pan American's new low-fare Rainbow Service to Europe went into effect. Douglas Super-6's are used on this transatlantic run.

• **The Parker Appliance Company** . . . The industrial and aircraft valve lines, created and manufactured by Parker for the past 20 years, have been acquired by Republic Manufacturing Company.

• **Phillips Petroleum Company** . . . The Materials Testing Reactor, now being operated under contract by Phillips at the National Reactor Testing Station, became "critical" on March 31 and is gradually being brought up to full power. The Materials Testing Reactor provides much needed facilities for determining the effect of intense radiation on materials considered for use in the structures, heat-transfer systems, and shields of new reactors. A schedule for its initial use was established many months ago. This reactor contains more than 100 ports in which specimens can be exposed to neutron bombardment. The reactor operates primarily on thermal, or slow, neutrons; however, it can also subject specimens to neutrons with intermediate and fast energies.

• **Piasecki Helicopter Corporation** . . . A 200,000 sq.ft. expansion program, involving a $2,000,000 investment, has been completed.

• **Pratt & Whitney Aircraft Division, United Aircraft Corporation . . .** The completion of initial tests for the U.S. Navy on an advanced version of the J-48 Turbo-Wasp has been announced. . . The Ford Motor Company has been licensed to manufacture the J-57 Turbo-Wasp jet engine without fee or royalties.

• **Republic Aviation Corporation** . . . A new division for research and development of advanced types of transonic and supersonic guided missiles has been created. Robert G. Melrose, M.I.A.S., has been named General Manager of the Guided Missile Division. Offices of the new division are located at 99 Broadway, New York City. . . A new long-distance record for sustained flight without refueling may have been established last March 18 when two U.S.A.F. F-84 Thunderjets flew over seven European countries for a distance of 2,800 miles in 4 hours and 48 min. The figures are being confirmed.

• **A. V. Roe Canada Limited and Canadair, Ltd.** . . . The Canadian version of the North American F-86E Sabre, now being manufactured by Canadair for the R.C.A.F., will be powered by the Avro Canada Orenda jet engine. The Orenda, which recently passed the official R.C.A.F. test, is rated at more than 6,000 lbs. of static thrust at sea level.

• **Servomechanisms, Inc.** . . . Two new 400-cycle pressure transducers, Static Pressure Transducer (TR101) and Differential Pressure Transducer (TR102), are being offered by Servomechanisms. These transducers of the electromagnetic type were designed to convert air pressures, static or differential as the case may be, into electrical signals for use in conjunction with precision instruments, analog computers, etc. Both meet the requirements of specification AN-E-19. TR101 has an applied pressure range of 0 to 760 mm. Hg. and an output voltage range of 0

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to 2.94 volts with 26 volts excitation. In the TR102 the applied pressure and output voltage ranges are, respectively, 0 to 684 mm. Hg. and 0 to 3.05 volts with 30 volts excitation.

• **Sikorsky Aircraft Division, United Aircraft Corporation** . . . The Sikorsky S-55 transport-type helicopter has been certified by the C.A.A. at a gross weight of 6,835 lbs. Its empty weight is 4,100 lbs. The delivery of the first unit to Los Angeles Airways was accomplished last March.

• **Solar Aircraft Company** . . . On last March 14, production operations were started at the new Wakonda Plant in Des Moines, Iowa. This new $7,000,000 300,000-sq.ft. plant is producing parts on a subcontract for the J-47 turbojet engine used to power the B-47 Boeing Stratojet. Parts for the Allison J-33, J-35, and J-71 jet engines are also to be produced at the Wakonda Plant.

• **Sperry Gyroscope Company, Division of The Sperry Corporation** . . . James F. Toole, who has been Treasurer and Comptroller of Sperry Gyroscope since 1949, has been named Vice-President and Treasurer of the company.

• **Trans World Airlines, Inc.** . . . The international Sky Tourist service has been increased to ten flights weekly in each direction between the United States and Europe. Six go via the Paris gateway; the remaining four go by way of London.

• **United Air Lines, Inc.** . . . H. Templeton Brown, Senior Partner of Mayer, Meyer, Austrian and Platt, of Chicago, was elected to United's Board of Directors to fill the vacancy created by the death on January 31 of Paul M. Godehn, Senior Partner of the same legal firm.

• **Vickers, Inc.** . . . Three new AN-approved fixed-displacement pump designs have been placed in production at Vickers. These designs are the two and three-gallon sizes (at 1,500 r.p.m.) and are identified as the PFA2, PFA3Y-2, and the PFA3Z-2. The latter two models differ only in the type of mounting pad provided. The volumetric efficiency of these pumps, which are rated at 3,000 lbs. per sq.in., is said to be 96 per cent; the overall efficiency is given as 92 per cent. The volumetric efficiency increases as the pressure is reduced. Small size and extremely high horsepower to weight ratio at rated loads and speeds are claimed as important characteristics of these accessories. Pressure pulsations generated by the new pumps plus their quiet operation is said to be made possible by the use of a metered valve plate. The AN-approved pumps were designed with straight-thread female-tubing fittings per specification AND-10050. To make the new pumps interchangeable with older models, they can be fitted with special valve plates having different fittings. A new brochure #4603, now available, describes these pumps in detail.

• **Westinghouse Electric Corporation** . . . Dr. Lewis Warrington Chubb, Director Emeritus of the Westinghouse Research Laboratories, died at his home on April 2.

Meet Your Section Chairman

Harris S. Campbell

Philadelphia Section

Harris Shirley Campbell has been actively engaged in the aeronautical field since 1928, the year in which he received his B.Sc. degree in Mechanical Engineering from Queen's University in Kingston, Ontario, Canada. (He was born about 85 miles to the north of Kingston in Arnprior, Ontario, on November 29, 1903.) From the time of his graduation until 1936, he worked successively as a Layout Draftsman for Canadian Vickers' Aircraft Department, as Design Draftsman on landing gears for Fairchild Aviation Corporation, and as Design Engineer on structural analysis, mechanical design, and patent development program for Pitcairn Autogiro Company and Autogiro Company of America. From 1936 to 1951, he served in the capacity of Consulting Engineer, specializing in the design and development of mechanical units for rotary-wing aircraft.

Mr. Campbell is currently Vice-President and Mechanical Engineer for Eastern Rotorcraft Corporation, designers of aircraft equipment. His immediate duties are concerned with the design and development of helicopter mechanical units and related equipment.

He has been associated with the design and development of mechanical units for the PA-39 autogiro, the XO-61 autogiro, the Navy XLRS-1 glider, and the Air Force XR-9 helicopter. His original designs have included: the Pitcairn PA-33 autogiro hub; the Firestone XR-9 helicopter transmission, rotor hub and control system; and the Eastern Rotorcraft Model T-100 rotor system. Mr. Campbell has had some 25 patents issued to him and has 18 other patent applications pending.

Mr. Campbell and his wife, the former Ida Southall whom he married in 1930, are the parents of 21-year-old David and 18-year-old Claire. Whenever he has any free time, Mr. Campbell goes in for camping and fishing, ice skating, and woodworking.

I.A.S. Sections

Atlanta Section

George W. Baughman, *Secretary*

At the organizational meeting of March 6, the Atlanta Section was formed, and Dave F. Berry, of the Technical Service Division, Georgia Division, Lockheed Aircraft Corporation, was elected interim Chairman of the newly formed group. Sharing the official spots are interim Vice-Chairman, Don W. Dutton, Director of Daniel Guggenheim School of Aeronautics, Georgia Institute of Technology; and interim Secretary-Treasurer, George W. Baughman, of the Technical Service Division, Gelac.

Thirty-one members and interested guests, representing many of the aeronautical interests of this section, aided in the formation of the new section at the Aeronautics Building at Georgia Tech. The program consisted of a tour of the School of Aeronautics. A demonstration and description of shock waves produced in the supersonic wind tunnel and on the water table concluded the technical session.

Boston Section

E. E. Larrabee, *Secretary*

The March 5 meeting was centered about a discussion by Dr. Ross A. MacFarland, Associate Professor, Department of Industrial Hygiene, Harvard School of Public Health, on the "Human Factors in Aeronautical Engineering."

Dr. MacFarland pointed out that most deaths in the economically productive fraction of the population are caused by accidents. Since many of these accidents could be avoided by considering the human factors involved in the use and maintenance of airplanes, it behooved aeronautical engineers to do so.

Some of the human factors that had to be considered were the limitations of the human animal, his normal habit patterns, and his susceptibility to his environment. Controls should be placed within the reach of normal pilots; critical controls—e.g., landing gear and landing flap handles—should be standardized from airplane to air-

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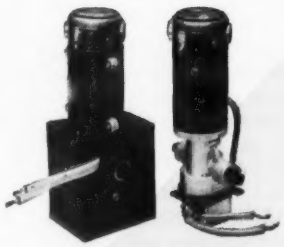

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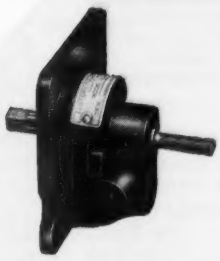

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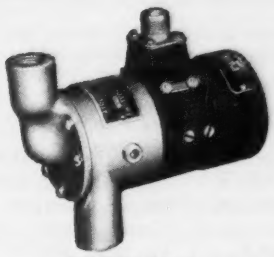

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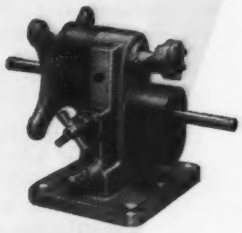

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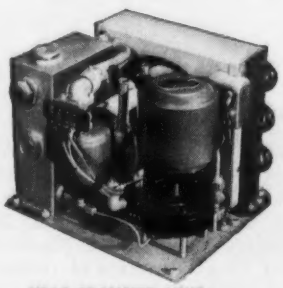

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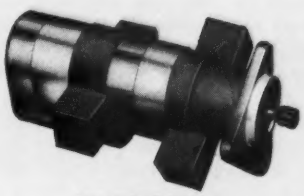

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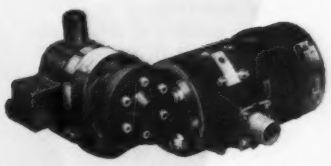
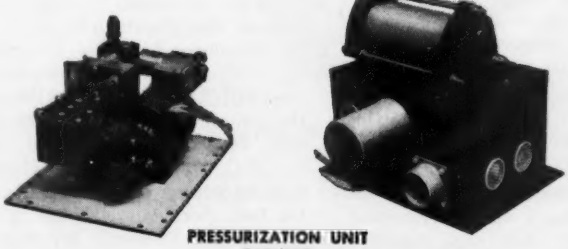


HYDRAULIC PUMP

OIL PUMP



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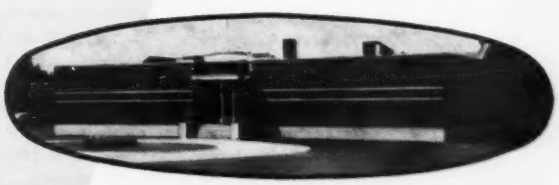

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Boston Section Speaker: *The speaker at the March 5 meeting and his wife, Dr. and Mrs. Ross A. McFarland, are shown with the chairman and treasurer of the Boston Section. From left to right they are: C. F. Savage, Chairman; Dr. McFarland; Mrs. McFarland; and J. D. Morrison, Treasurer.*

plane, and adequate oxygen supplies should be provided above 13,000 ft. Explosive decompression of pressure cabins would probably result in passenger death at altitudes of 40,000 ft. or greater. The trend toward older pilots in commercial aviation required that consideration be given to their decreased audio and visual sensitivity.

In the business portion of this meeting, the members voted that the I.A.S. Boston Section affiliate with the E.S.N.E. The meeting closed with a showing of a United Air Lines' promotional film, *Of Men and Wings.*

Baltimore Section

M. Francis Taylor, *Secretary*

The thirty-fifth meeting of the Baltimore Section was held on March 12 at The Johns Hopkins University. The chairman called the meeting to order at 8:30 p.m. with approximately 75 members and guests present.

After the presentation of a "tea cosy imported directly from England for the occasion" to make our speaker feel at home, the chairman introduced Glenn Hobday, Resident Advisory Engineer to The Glenn L. Martin Company for The English Electric Company (designers of the Canberra). Mr. Hobday spoke on "British and American Design Practices for Aircraft."

The speaker introduced his subject by tracing the organization of the design team established by English Electric for the design of the Canberra. The English Electric Company itself entered the aircraft design and manufacturing field as far back as 1911, but these early activities ceased in 1926. During World War II, the company set such an excellent production record that it was encouraged to set up an aircraft design organization. Joint studies by the Ministry of Supply and the Air Ministry established the design requirements for a high-altitude light bomber that became the Canberra.

Mr. Hobday indicated that the major organizational difference between British and American engineering is one of simplicity and complexity. The American firms seem to handle a larger number of separate projects simultaneously than does the average British firm. This, together with greater manpower, leads to far bigger and more complex design organizations. The American firms use their much greater manpower to concentrate on jobs over relatively short periods, but the overall effort expended remains approximately the same. Another difference is the number of trained engineering specialists produced in America. The English cannot afford to use trained engineers for the various forms of budgeting as is found in many American plants.

Effective air power is a question not only of performance but also of the number of aircraft that can be put into the air at any given time, the speaker stated. Aircraft on the ground when needed are useless, and, in modern warfare, aircraft are used up at an extraordinary rate. In these circumstances, unnecessary complication must be avoided. That is why the English do not fit so many emergency and duplicate systems to the English aircraft.

The British firms work to closer tolerances and smaller edge distances, yet they do not have the machine-tool capacity of the American industry. They appear to concentrate on individual components for weight-savings rather than on overall design, but they also compare the worth of the weight-saving with the design and manufacturing cost. Although the strength requirements of the two countries appear to differ considerably, the strength of the English airplane would meet the requirements of R-1803 with one major exception and probably one or two minor exceptions. The major exception would be flying controls, where the English requirement is approximately one-half. In general, both countries have much the same technical approach and detail design approach. The American approaches do appear to be more conscious of fatigue problems.

Mr. Hobday commented on the similarity of flight-test work and equipment, but he pointed out that the British usually do their flight testing on several different airplanes over a long period of time. He observed that there seems to be a much greater tendency toward high wing loadings in America than in England. There is one great difference in the basic design, particularly in bombers, which should be given more attention and thought.

The speaker concluded his talk with the statement that there is a surprising measure of agreement between the individual outlooks on either side of the Atlantic and that certainly the future lies in mutual cooperation.

Following a lively discussion period, reluctantly halted by the chairman, the Program Committee presented an excellent United Air Lines' movie entitled *United 6534.*

The meeting was adjourned at 10:30 p.m.

Chicago Section

Alfred F. Stott, *Secretary*

The Chicago Section held its Annual Student Paper Contest on March 13. Five schools were invited to participate—namely, University of Illinois (Urbana), University of Illinois (Chicago), Illinois Institute of Technology, Aeronautical University, and University of Notre Dame. Twenty-five members and guests attended a dinner in the Student Union at Illinois Tech.

Fifty-five persons attended the meeting that was called to order at 8:15 p.m. by Vice-Chairman Dr. H. L. Hull. He introduced Lee Sims, Chairman of the Student Activities Committee, who presided. Mr. Sims outlined the rules of the contest and introduced the judges who were Lt. Col. Harold Penne, U.S.M.C., Naval Air Station, Glenview; Richard Schram, C.A.A.; and Ralph N. Du Bois, Ford Motor Company's Airplane Engine Division. Mr. Sims then introduced the first contestant, Wendell J. Thompson, University of Illinois (Urbana), who spoke on "Fatigue as Related to Aircraft Structures." Lyman Welliver, Aeronautical University, was introduced and presented a paper entitled "The Trend from Flying Boats to Water Based Aircraft." Both men made excellent presentations of their papers, making it difficult for the judges to determine the winner. Mr. Du Bois, spokesman for the judges, finally announced the winner to be Mr. Welliver. Mr. Sims presented the trophy to the winner. In addition, cash

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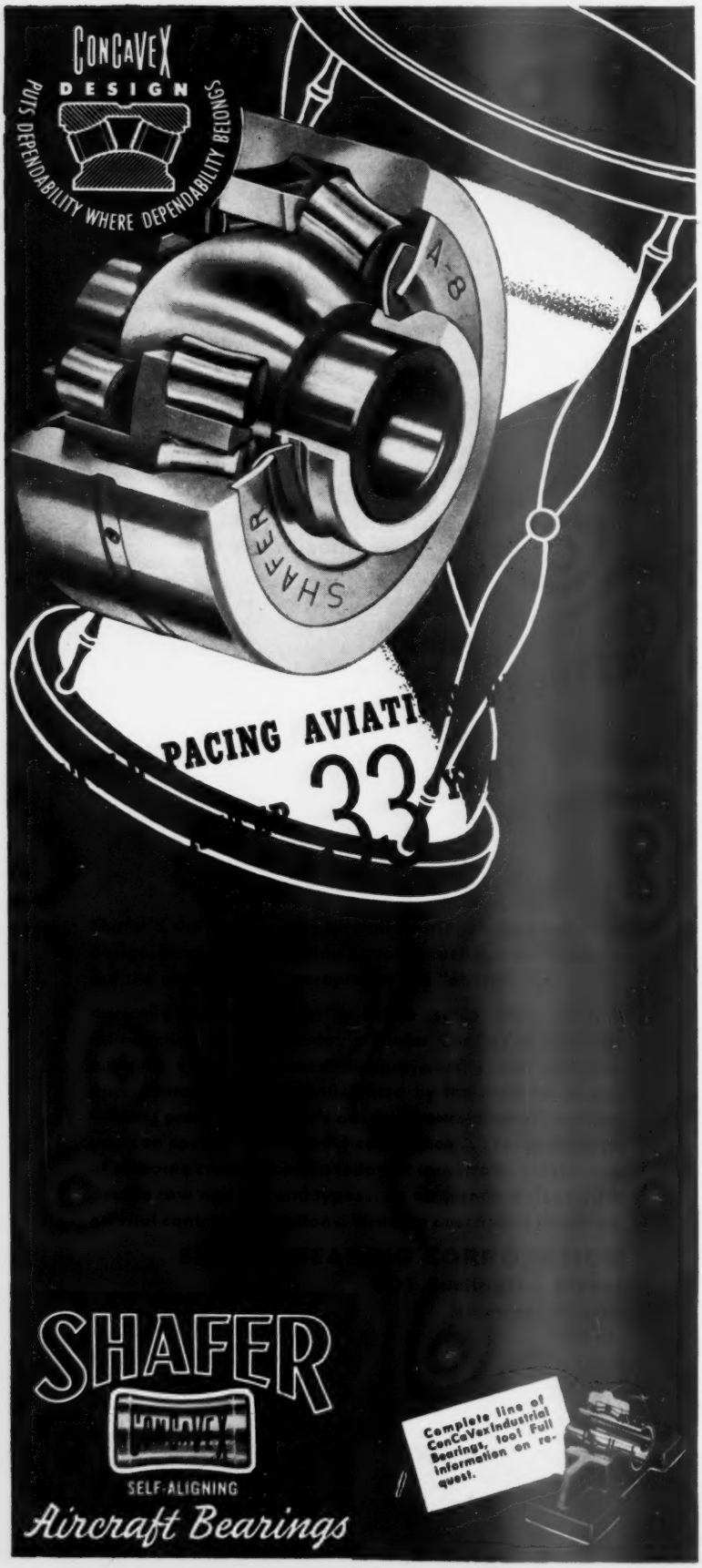

awards were presented to both contestants.

While the judges were in conference, an Air Force film on the Omni Range was shown. The meeting was adjourned at 10:00 p.m.

Detroit Section

K. E. Smith, *Secretary*

At the February 8 meeting, 80 members and students heard the eminent Dr. Sidney Goldstein discuss the basic problems encountered in the establishment of Haifa Technion in the new state of Israel. Dr. Goldstein explained that for the last 14 months his efforts have been directed toward the organization and administration of this technical institute to train and supply technicians and engineers. Dr. Goldstein pointed out that many of the conventional methods used in organizing an activity of this type were not applicable because of the nature of the territory, the natural resources available, and the extremely rapid expansion in population. The organization of the government has proceeded rapidly and efficiently, and the population as a whole is fiercely democratic. Dr. Goldstein is Dean of Aeronautical Engineering and Vice-President of Haifa Technion.

Dr. Goldstein graciously submitted to a question and answer period after his talk, during which several basic problems regarding the philosophy of instruction at the technical institute were discussed.

An informal dinner meeting in Dr. Goldstein's honor was held prior to his talk. Peter Altman, Vice-President of Continental Motors Corporation, was the Coffee Speaker. Mr. Altman discussed briefly the trends in the aircraft industry and pointed out a few of the important problems that he felt merited immediate attention. Among these problems were: (a) ways of raising upper-limit operating temperature of jet engines; (b) lowering of the landing speed of airplanes to the point where they approach the convertiplane configuration; and (c) gust alleviators to lower the aircraft structural requirements.

Professor A. Locke of Wayne University presented an interesting free-flight model demonstration of a convertiplane. Several successful flights were made in the Science Hall of Wayne University prior to Dr. Goldstein's talk.

Hagerstown Section

Robert E. Braus, *Secretary*

The regular monthly meeting of the Hagerstown Section was held on February 29 at the American Legion Club.

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Dinner was served to 66 members and guests at 7:00 p.m. The meeting was called to order at approximately 8:30 p.m. by Section Chairman E. E. Morton who turned the meeting over to H. C. Billings of the Program Committee.

Mr. Billings introduced the speaker of the evening, Col. George W. Goddard, Chief of the Photographic Laboratory at Wright-Patterson Air Force Base, Ohio.

Colonel Goddard, who contributed much to the development of aerial photography, presented an interesting and informative talk illustrated by slides and three-dimensional strip films. He began by showing pictures of the first crude camera installations on early airplanes and told of the development of aerial photography through the years to the present complex camera installations in modern high-altitude jet-powered airplanes. The major steps in development were illustrated by slides showing inboard profiles of photographic airplanes.

The audience, supplied with polaroid glasses, enjoyed approximately 30 min. of three-dimensional strip films of American, European, and Asiatic scenes of both peaceful and war-torn cities and countrysides. The pictures, of unusually natural quality, were taken at the speed of 300 to 500 m.p.h. Colonel Goddard pointed out that they would be of equal clarity even if taken at 3,000 m.p.h.

Mr. Morton closed the meeting after the conclusion of the films.

Montreal Section

H. V. Braceland, *Secretary*

A joint meeting of the I.A.S. Montreal Section and the Engineering Institute of Canada was held on February 7. The guest speaker was C. C. Bogart, of the Department of Transport. The subject of his most timely address was "Air Traffic Control."

Mr. Dyment, Chairman of the meeting, introduced the guest speaker by stating that Mr. Bogart commenced his aviation activities in 1928 as a pilot and continued as such until 1939. Early in 1939, he established the first control tower in Canada. Since that time, Mr. Bogart has been responsible for the establishment of control towers and air traffic control across Canada. Mr. Dyment stated the necessity of air traffic control and of the work that the I.C.A.O. and the I.A.T.A. are doing to solve many of the current problems.

Mr. Bogart introduced the subject of "Air Traffic Control" by indicating the great need for such control and stressed the importance of accurate information for aircraft traveling Canada's air highways.

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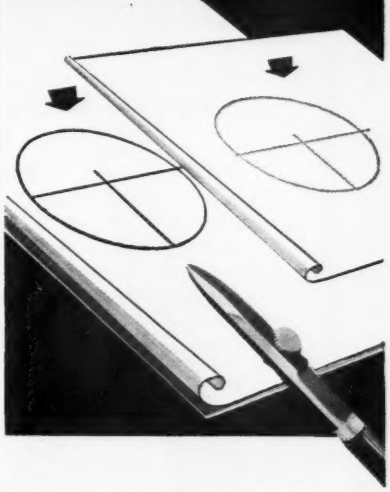

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The speaker gave a general synopsis of air traffic control and at the same time explained the various terms associated with it such as "control area." He outlined the functions of each section of air traffic control by detailing the necessary steps taken as soon as a pilot files a flight plan either I.F.R. or V.F.R.

Experience has shown that the majority of delays on instrument approaches is caused by missed approaches. Mr. Bogart indicated that a good time interval for landing is 3 min., but the usual landing rate is 5 min.; however, in many cases, due to missed approaches, etc., the time is extended to 15 min.

It was the opinion of the speaker that no new equipment or facilities would be required for jets, and he estimated on the experience gained with military jet aircraft that no more complication than with piston aircraft was anticipated. It was not intended that any priority be given to jet transport aircraft. It was possible, however, that jet transport may be held at 20,000 ft. and then be given clearance for a "straight in" approach. This method would not endanger or disrupt other traffic in the area.

To increase the accuracy of pilot reports, air-borne radar may be of great assistance. This would result in more rapid approaches, but, because of the high expense and recent improvements, it is expected that no installation will be made of new equipment until some reasonably workable compromise is available.

In summing up, Mr. Bogart outlined the major duties of air traffic control: (a) to assist the pilot; (b) to lend assistance for take-off at airports; (c) to ensure separation, both lateral and vertical; (d) to inform the pilot of hazardous conditions; (e) to search and rescue; (f) to produce as far as possible efficient and quick landings; and (g) to maintain an orderly flow of air traffic.

A. L. Lilley, Test Pilot, Canadair Limited, thanked the speaker, and the meeting was adjourned by the presiding chairman.

Philadelphia Section

Emily D. Rogers, *Secretary*

The March 5 meeting was held at the Engineers Club of Philadelphia with an attendance of over 70 for the dinner and about 150 for the meeting.

Commander Gordon Ebbe, Superintendent of the Aero-Photographic Experimental Laboratory, Naval Air Material Center, Philadelphia Naval Base, spoke on "Arctic Aircraft Operations." His talk was accompanied with unusually fine slides.

In reviewing the work of arctic aircraft operations, he covered the following topics: (a) operations essential in the exploration and drilling for oil necessary in Naval Petroleum Reserve #4; (b) Eskimo life in and around Northern Alaska; (c) Eskimo whaling operations; (d) camp life at Point Barrow; (e) Arctic air lift operations in support of Naval Petroleum Reserve #4; (f) ptarmigan flight to the North Pole; (g) ski jump operations 300 miles out on the Arctic Ocean ice; (h) cat-train operations across the frozen tundra; (i) winter ice carnival at Fairbanks; and (j) Mount McKinley.

Toronto Section

R. T. Gibson, *Secretary*

The guest speakers at the March 5 meeting were R. M. Woodham, of Cornell University's Guggenheim Aviation Center, and William Stieglitz, Safety Engineer, Republic Aviation Corporation. The speakers were introduced by Chairman K. M. Molson to approximately 50 members and guests gathered in the Mechanical Engineering Building, University of Toronto.

Mr. Stieglitz chose as his theme, "Some Aspects of Accident Prevention." He pointed out that the basic elements of good design—good aerodynamics, good flying characteristics, and sound

structure—are not enough. Detail design that does not regard human limitations serves to build in personnel error. Moreover, the size of the parts bears no relation to the size of the accident. This point was illustrated in several disastrous crashes that were caused by poor design of seemingly insignificant pieces of equipment.

Speaking of the much used term, "pilot error," Mr. Stieglitz asked the question: "Who made the first mistake?" All too often aircraft have accidents built in, just waiting to happen. Poorly located controls may prove disastrous, if the pilot's hand reaches the wrong one in an emergency.

In conclusion, Mr. Stieglitz emphasized the need to analyze a design, to discover all possible sources of error, and then to get rid of them.

R. M. Woodham told of the work of the Guggenheim Center in "Research in Aviation Safety." Speaking of the machine, the medium, and the man, Mr. Woodham discussed the need for improvements in the machine, the chances to overcome the restrictions of the medium, and the necessary recognition of the man's limitations.

Improved cockpit design, better visibility for the pilot, and use of nonflammable fuels and hydraulic fluids all contribute to a better machine. Automatic landing equipment, better wind and weather forecasting, and airport and traffic-control refinements are ways of overcoming the restrictions of the medium. Mr. Woodham concluded by saying that the medical profession has been most helpful in determining the limitations of the man. It has been demonstrated that crash accelerations of over 50 g can be sustained without serious injury.

Following a lively discussion period, the speakers were thanked by W. H. Jackson, Contracts Manager of de Havilland Aircraft Company.

Washington Section

Ernest Werner for J. H. Sidebottom, *Secretary*

At the March 4 meeting after Bill McNary, of Piper Aircraft Corporation, and R. M. Harmon, of Beech Aircraft Corporation, read their papers, "Past 20 Years of Piper Personal Airplane Design" and "Design Considerations in Executive Aircraft," interlocutor "Doc" Hartranft—and he did it well—got a lively question and answer session going which had to be called off because of time.

Mr. McNary had colored slides showing the various aircraft Piper has dreamed up during the past 20 years. He followed each model along, giving solid credit to the "outside designers"—the Sunday morning quarterbacks—who

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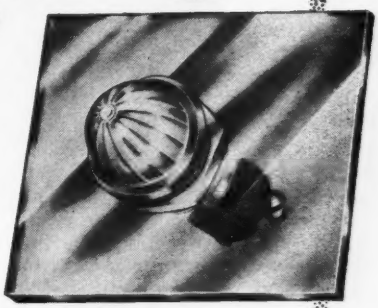

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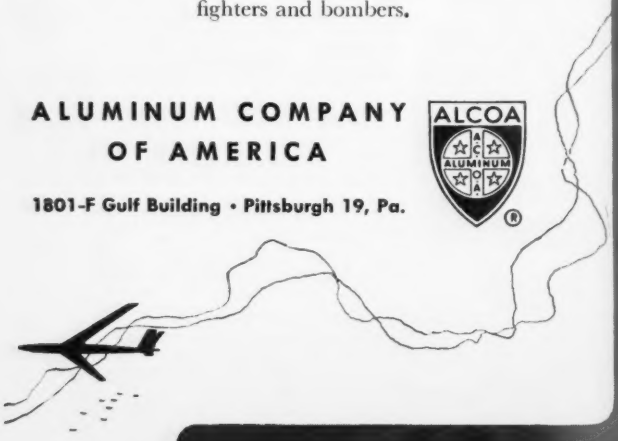

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have always given the cue to Piper as to what they want in small aircraft. The increased pay load, range, speed, comfort, utility, etc., of the various Piper models were impressive. These factual details lend themselves to comparison, but how about the increased prices? Considering the many added features and the present value of the dollar, it looks as though Piper is selling a full ton of coal on today's market, and today's airplane is a far cry from those of 20 years ago. If Piper's publicity people ever get out a little booklet fashioned after Bill McNary's paper, I'd like to be the first on the mailing list.

Mr. Harmon's paper dealt with design considerations in executive-type aircraft. He outlined categories of aircraft by weight, considering the light aircraft as Piper's baliwick, and discussed the various operational requirements desirable in aircraft from the Bonanza and Navion up to the largest four- and six-engined jobs. The typical executive wants to fly his own plane, but the percentage of professional pilots goes up as the weight and size increase. Executives want aircraft that compare favorably with air-line speeds. The conclusion was that the piston engines' limitations will force the manufacturers to take a longer look at the various jet possibilities. In any event, given a potential market, sufficient working capital, and time, we will eventually get the executive model that will incorporate all the features the executive wants, but he will have to pay for it.

After these two interesting papers were read, "Doc" Hartranft put the Messrs. McNary and Harmon "on the spot." One practical questioner stated that he was a potential customer for an executive aircraft and was impressed by the technical progress being made but that the prices quoted were out of his reach. What he wanted to know was whether there was any manufacturer who was considering the "Junior Executive."

Neither Piper nor Beech appears to be worried about helicopters. Conceding more versatile operational possibilities, the fixed wing has a permanent niche in the field, considering the initial cost and maintenance of any helicopter now available. Mr. Harmon had a good answer on roadable aircraft when he commented that it has taken us 50 years to develop a practical automobile that stands up on today's highways and nearly that time to get a fair airplane. It looks as though it will be many years before we see many combinations floating around. "Doc" Hartranft squeezed every possibility of getting an argument going between the guest speakers, but they held their ground, and it turned out to be one of the best meetings we have had in a long time. Our program committee should be complimented: first, the good dinner at the Army-Navy Club; second, good speakers and a lively discussion; and last, an instructional and entertaining color movie, *Air Age*, developed by the State of Idaho Aviation Directorate.

Student Branches

Cal-Aero Technical Institute

The February 20 meeting was called to order by Chairman Andre Rieben who introduced R. A. Wagner, Chief Engineer, McCulloch Motors Corporation, and A. W. Bayer, Flight Director, McCulloch Motors. Mr. Wagner spoke on "The Influence of Vibration in Helicopter and Blade Design" and accompanied his lecture with a film on an experimental model of McCulloch's latest type of helicopter. The meeting was adjourned to the airport where Mr. Wagner, with Mr. Bayer at the controls, demonstrated the performance and maneuverability of the McCulloch MC-4 experimental helicopter.

California State Polytechnic College

On February 20, Price MacVeigh Keeler, Senior Electronics Engineer, Consolidated Vultee Aircraft Corporation, spoke on the "Developmental Steps for Flush Antenna Installation on the Convair T-29 Aircraft." The talk, which was presented before 65 students, was illustrated with slides. Chairman Herbert Pearce presided.

"Titanium—A Structural Metal for Aircraft" was the subject on which Lloyd Eber, senior aeronautical engineering student at Cal Poly, spoke at the February 25 meeting. A film from Consolidated Vultee Aircraft Corporation entitled *Target Peace* ended the meeting. Chairman Pearce presided; 30 students were present.

▶ The March 12 meeting, attended by 160 persons, was Cal Poly's "First Annual Engineering Progress Meeting." The purpose of this annual progress meeting is to acquaint the Engineering Division as a group with recent progress in the fields of engineering and science by inviting an engineering authority to speak. Edward H. Heinemann, Chief Engineer for the El Segundo Division of Douglas Aircraft Company, Inc., was this year's selection.

The meeting was called to order at 8:00 p.m. by Chairman Pearce, who introduced E. W. Robischon, I.A.S. Western Manager, Mr. Robischon in turn introduced the speaker, Mr. Heinemann, whose topic was "Recent Developments in Aircraft Design."

A DEMONSTRATION FOR CAL-AERO TECH

Standing from left to right before the McCulloch MC-4 experimental helicopter, just prior to its take-off on a demonstration flight, are: Frank R. Seery, Stress Instructor at Cal-Aero; A. W. Bayer, Flight Director for McCulloch Motors Corporation; R. A. Wagner, Chief Engineer for McCulloch; P. A. Rieben, Chairman, Cal-Aero Student Branch; and J. W. Bourret, Secretary-Treasurer, Cal-Aero Student Branch.

Skyrocket Admirers: *Inspecting a desk model of the D-558-2 Skyrocket are from left to right: Lester W. Gustafson, Aeronautical Department Head, California State Polytechnic College; Edward H. Heinemann, Chief Engineer, El Segundo Division, Douglas Aircraft Company, Inc.; E. W. Robischon, I.A.S. Western Manager; and Herbert E. Pearce, Chairman, I.A.S. Student Branch at Cal Poly.*

In his talk Mr. Heinemann discussed the AD-1 Skyraider, the F3D Skyknight, the XA2D Skyshark, the XF4D-1 Skyray, the D-558-1 Skystreak, and the D-558-2 Skyrocket. Models of each of these planes were passed around in the audience.

The meeting was concluded by the showing of three films: *The Douglas Skyraider, The Douglas Skyrocket,* and *Naval Carrier Operations in Korean Waters.*

University of Cincinnati

Chairman Dale A. Benethum called the March 6 meeting to order for the purpose of filling the recently vacated positions of Vice-Chairman and Secretary. As a result, Jim Thrailkill was elected Vice-Chairman and Vince Kearney became Secretary. Twenty-five persons were present.

A film, *The A.B.C.'s of G's,* was shown at the March 14 meeting. Fifty students were present; Chairman Benethum presided.

University of Detroit

On March 5, 26 students heard Dr. Frederick W. Ross, Professor of Aeronautical Engineering, University of Detroit, give an illustrated talk on the "Ross Control System." Chairman George Paul Himes presided.

University of Florida

C. C. LaVene, Job Representative, Douglas Aircraft Company, Inc., spoke at the February 26 meeting on the "Advancement of the Aircraft Industry." Chairman Roy F. Dutton presided; 20 students were in attendance.

University of Illinois

Professor R. W. McCloy, Aeronautical Engineering Department, University of Illinois, spoke at the March 5 meeting on "The Morphology of Flight Propulsion." Twenty-one students were present.

Indiana Technical College

On February 7, an election of officers was held with the following results: Chairman, Harold Swallow; Vice-Chairman, Albert Baciak; Secretary, Roger Kauffman; and Treasurer, George Greeneberg. Two films, *Hamilton Hydramatic Prop* and *Airplane Structures,* were shown. Chairman John W. Whitehurst presided; 19 students were present.

On February 21, with 14 persons in attendance, retiring Chairman Whitehurst led the meeting held in conjunction with the Graduation Banquet. Benton S. Lowe, Industrial Relations Director of Indiana Technical College, and James Kelly, Owner-Operator of Kelly's Flying Service, gave impromptu talks. Mr. Forbes was named the winner of the Outstanding Student Award for the 1951–1952 winter term.

Massachusetts Institute of Technology

On March 18, a film entitled *The Guardian Angel* was shown to the 35 persons in attendance. Chairman James Flanders presided.

Northrop Aeronautical Institute

At a recent meeting, A. Armond Tolomeo was elected Chairman; Harlan B. Gould, Vice-Chairman; Arthur B. Stolins, Jr., Recording Secretary; Arthur Eck, Corresponding Secretary; and Alfred Andreoli, Treasurer.

Rensselaer Polytechnic Institute

At the March 19 meeting, which was attended by 40 persons, Prof. A. J. Fairbanks, Associate Head of R.P.I.'s Aeronautical Engineering Department, introduced the speaker, Robert E. Gorton, Chief Vibrations Engineer, Pratt & Whitney Aircraft Division of United Aircraft Corporation. Mr. Gorton presented an illustrated lecture on "Vibration Problems in Aircraft Power Plants." Chairman Frank T. Suppies presided.

Agricultural and Mechanical College of Texas

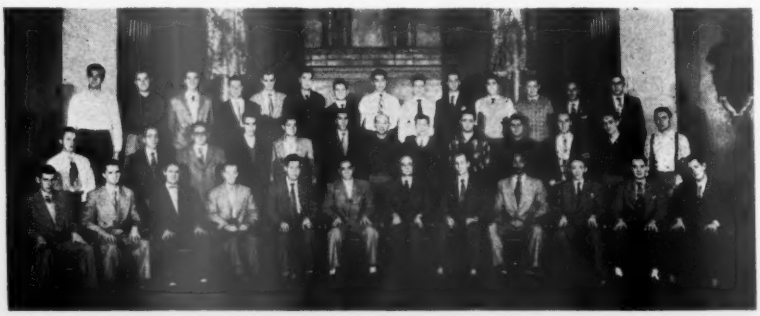
At the March 5 meeting, Lawrence Whaley was elected Treasurer. The business meeting was followed by the showing of two films. The first was a March of Time picture entitled *Flight Plan for Freedom;* the second was an Air Force training film. Chairman Richard T. Cliffe presided; 24 students were present.

The University of Texas

With Chairman Soren C. Jenson, Jr., presiding at the March 17 meeting, 27

NEW YORK UNIVERSITY STUDENT BRANCH

The members of the I.A.S. Student Branch at New York University are shown in a recent picture, together with the Faculty Adviser, Frederick K. Teichmann, Professor and Chairman, Department of Aeronautical Engineering, N.Y.U. Mr. Teichmann is seated in the front row, seventh from the left.



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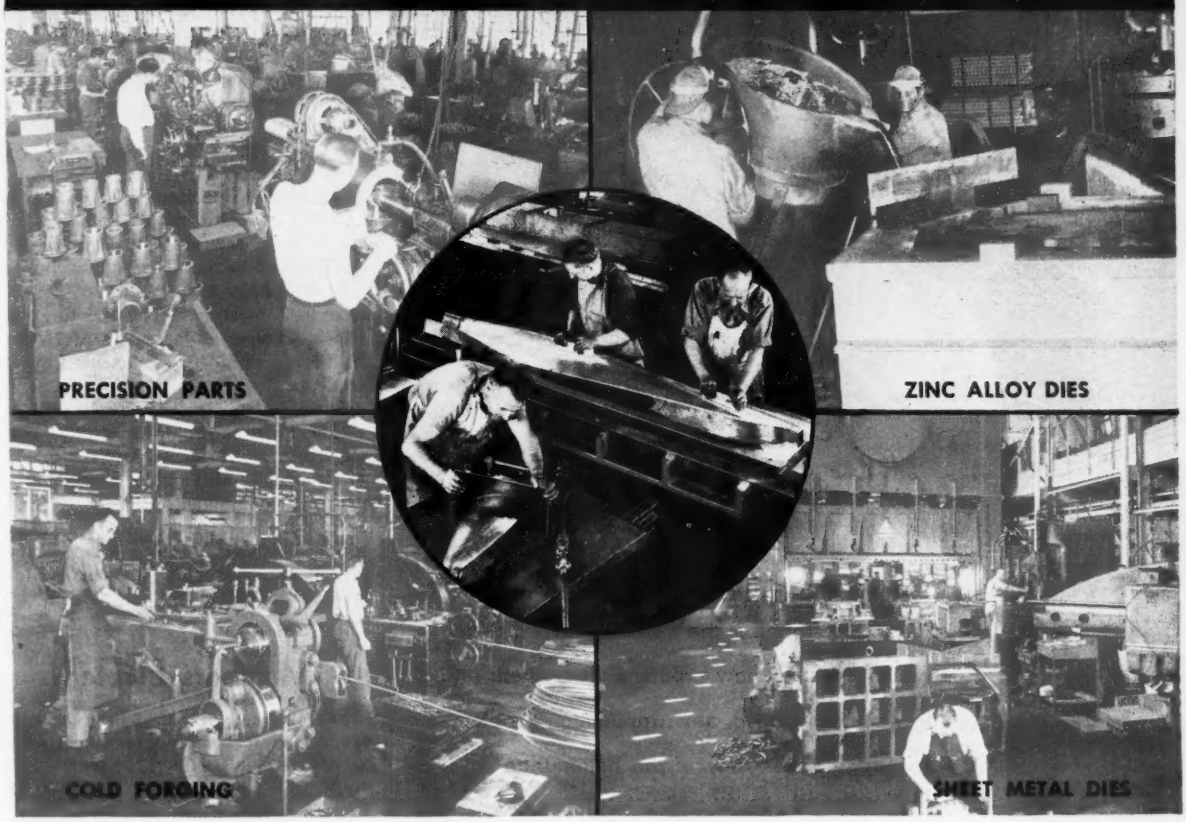

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University of Tulsa

Chairman E. W. Garrison presided at the March 27 meeting at which two films, *A Plane Is Born* and *The Earth's Rotation*, were shown. Twenty persons were present.

United States Naval Academy

Lieutenant Commander R. M. Sewell, U.S.N., Instructor of Electronics, U.S. Navy Post Graduate School, Annapolis, Md., spoke on the "Duties of a Junior Officer Within the Squadron" at the March 7 meeting. The meeting, at which Chairman James S. McNeely, Mid'n 1/c, presided, was attended by 37 students.

On March 28, an election of officers was held with the following results: Co-Chairmen, C. H. Kruse, Mid'n 2/c, and J. A. Muka, Mid'n 2/c; Vice-Chairman, C. H. Builder, Mid'n 3/c; and Secretary, J. J. Olsen, Mid'n 3/c. A technicolor film, *NACA Research*, completed the meeting. Chairman McNeely presided, and 31 were present.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to MEMBER Grade

Arrow, Bernard, B. of A.E., Vibration Engineer, Piasecki Helicopter Corp.

Bell, Clarence O., Vice-President, Secretary & Gen. Mgr., Aero Engineering, Inc.

Bensen, Igor B., M.E., Chief of Research, The Kaman Aircraft Corp.

Bielkowicz, Peter, Ing. Civil d'Aeronautique, Asst. Prof., Engineering Div., Brown Univ.

Bloch, Rene M., M.A., 1/C Technical & Management Control Engineer, Overhaul & Repair Yards, French Naval Air Force.

Boughton, Edward R. S., Sr. Design Engineer, A. V. Roe Canada, Ltd.

Campbell, Anthony J., Chief Test Engineer, Douglas Aircraft Co., Inc. (Long Beach).

Clark, Bruce D., B.S., Head of Aircraft Group, British Joint Services Mission (Technical Services) (Washington, D.C.).

Delameter, Henry D., B.S., Proj. Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Dunsmore, Chester L., M.A., Engineer, Marquardt Aircraft Co.

Engum, Douglas B., M.S. in Ae.E., Stress Analyst, Douglas Aircraft Co., Inc. (Long Beach).

Fero, Lester K., B.S.Ae.E., Administrative Asst. to Chief Structures Engineer, Bell Aircraft Corp.

Fritz, Dwain E., Chief Engineer, Jack & Heintz, Inc.

Gazley, Carl, Jr., Ph.D., Development Engineer, General Electric Co. (Schenectady).

Harker, James T., S.B., Aviation Industry Specialist, Silicone Products Dept., Chemical Div., General Electric Co. (Waterford, N.Y.).

Johnson, H. Clay, Jr., S.M. in Ae.E., Supervisor of Structural Dynamics, The Glenn L. Martin Co.

Kaushagen, W. Maurice, M.S. in Physics, Research Physicist & Asst. Dept. Head, Physics Dept., Cornell Aero. Lab., Inc.

Kuhn, John K., B.S.M.E., Combustion Group Supervisor, Marquardt Aircraft Co.

Lazar, Edward F., B.S.E.E., Dir., Federal Dept., Sperry Gyroscope Co. Div., The Sperry Corp.

Lincoln, David C., M.S. in E.E., Proj. Engineer, Sperry Gyroscope Co. Div., The Sperry Corp.

Longhurst, William S., Test Pilot, Canadair, Ltd. (Montreal).

Luce, Richard W., Jr., M.S., Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Martin, John L., Jr., M.S. in Ae.E., Lt. Colonel & Asst. Prof. of Electrical Engineering, U.S.A.F. Institute of Technology (Wright Field).

Monroe, William R., M.S., Group Engineer, North American Aviation, Inc. (Los Angeles).

Moore, Cecil R., Mgr., Jack & Heintz, Inc. (Pacific Coast District).

Morris, Brooks T., A.B. & G.E., Administrative Engineer, Marquardt Aircraft Co.

Murphy, Robert C., B.S. in Ae.E., Dynamicist "A,"—Flutter Analysis, Northrop Aircraft, Inc.

Norsworthy, Edward C. V., B. Eng. (Mech.), General Service Supervisor, Canadair, Ltd. (Montreal).

Powers, Patrick W., M.S. in M.E., Capt. & Instructor in Aerodynamics & Propulsion, Guided Missiles Dept., The Artillery School, U.S.A. (Ft. Bliss).

Reymann, Bernard A., B.E., Group Engineer—Stress, The Hayes Aircraft Corp.

Rott, Nicholas, Ph.D., Assoc. Prof., Cornell Univ.

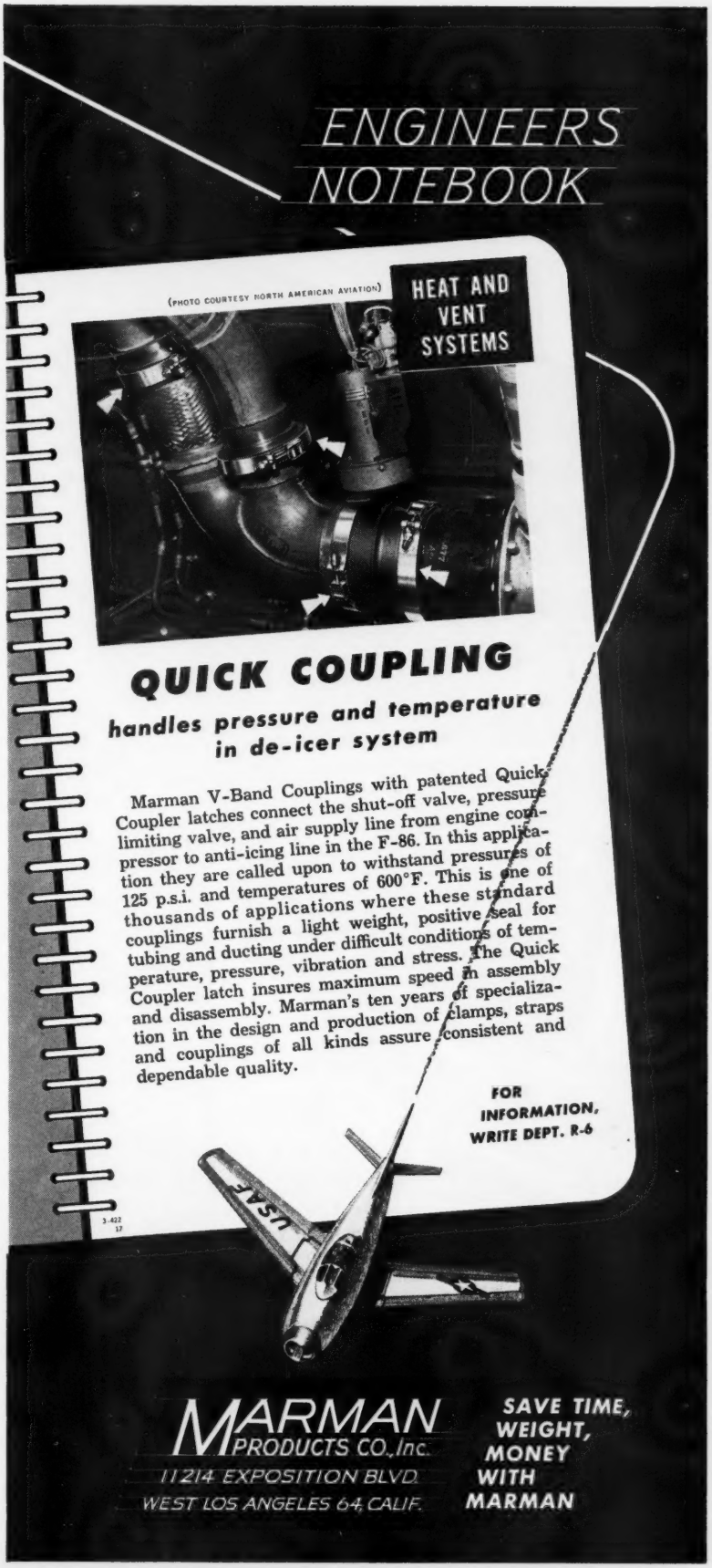
Russel, George M., B.S., Flight Safety Engineer, Northrop Aircraft, Inc.

Sandelius, John R., B.S. in Ae.E., Designer "A," Preliminary Design, Boeing Airplane Co. (Seattle).

Sanford, Richard W., B.S. in E.E., Chief Engineer, Aircraft Armaments, Inc.

Soukhanov, Ivan M., Dr. Ing., Stress Analyst, The Glenn L. Martin Co.

Tatham, Norman J., B.S.C.E., Design Group Leader, Mechanical Controls & Wind Tunnel Model, Douglas Aircraft Co., Inc. (Long Beach).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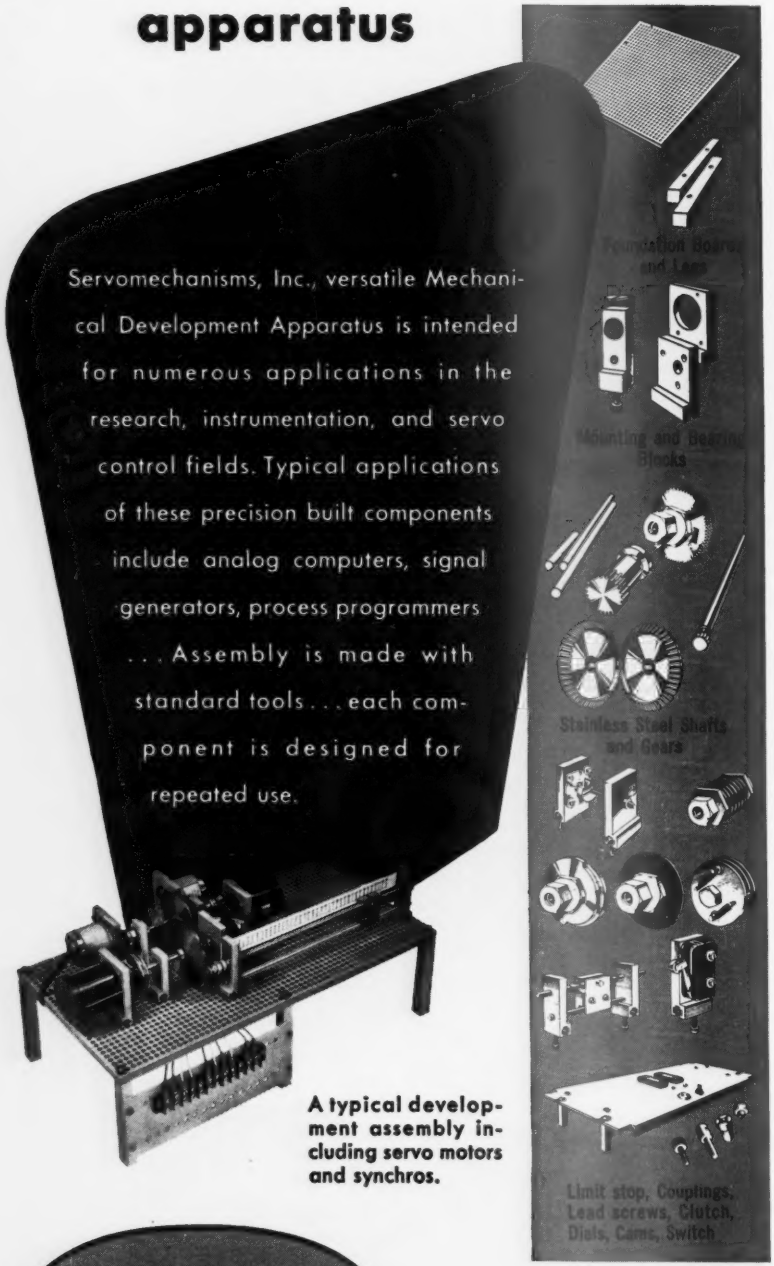
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Thomas, David D., Planning Officer, C.A.A. (Washington, D.C.).

Wall, Marvin R., M.S.Ae.E., Development Engineer, Oklahoma Power & Propulsion Lab., Oklahoma A. & M. College.

Ward, Jack C., B.S.M.E., Proj. Coordinator, Consolidated Vultee Aircraft Corp. (Ft. Worth).

Transferred to MEMBER Grade

Brown, Sydney S., B.S., Weight Engineer, Structural Weight Estimating Unit, North American Aviation, Inc.

Christensen, Albert T., B.Ae.E., Application Engineer, General Electric Co.

Evans, Elma T., B.S., Librarian, Cornell Aero. Lab., Inc.

Elected to Associate Member Grade

Bindewald, George J., Aero. Sales & Service Mgr., Instrument Div., Thomas A. Edison, Inc.

Connelly, J. Fred, President, Canton-Carey Sales, Inc.

Davies, Charles, Engineer, Canadair, Ltd. (Montreal).

Keith-Davies, E., Managing Dir., Cambrian Air Services & Managing Dir., Keith & Boyleston, Ltd.

Lockwood, Harold J., A.M., Cons. & Research Engineer, Industrial Sound Control, Inc.; Prof. of Engineering, Trinity College.

Mettes, Joseph L., Electronic Test Technician, Bell Aircraft Corp.

Mustard, William L., B.Ae.E., District Mgr. (Dayton), Link Aviation, Inc.

Elected to Technical Member Grade

Archer, Richard D., B.E. (Aero.), Teaching Asst. & Graduate Student in Aero. Engineering, Univ. of Minnesota.

Batiste, Stanley, A.A., Layout Draftsman, Chase Aircraft Co., Inc.

Copley, Richard J., Aerodynamicist "B," Aerodynamics Group, Engineering Dept., Douglas Aircraft Co., Inc. (Santa Monica).

Dunsby, John A., B.Sc. (Eng.), Tech. Dept., The Royal Aero. Society.

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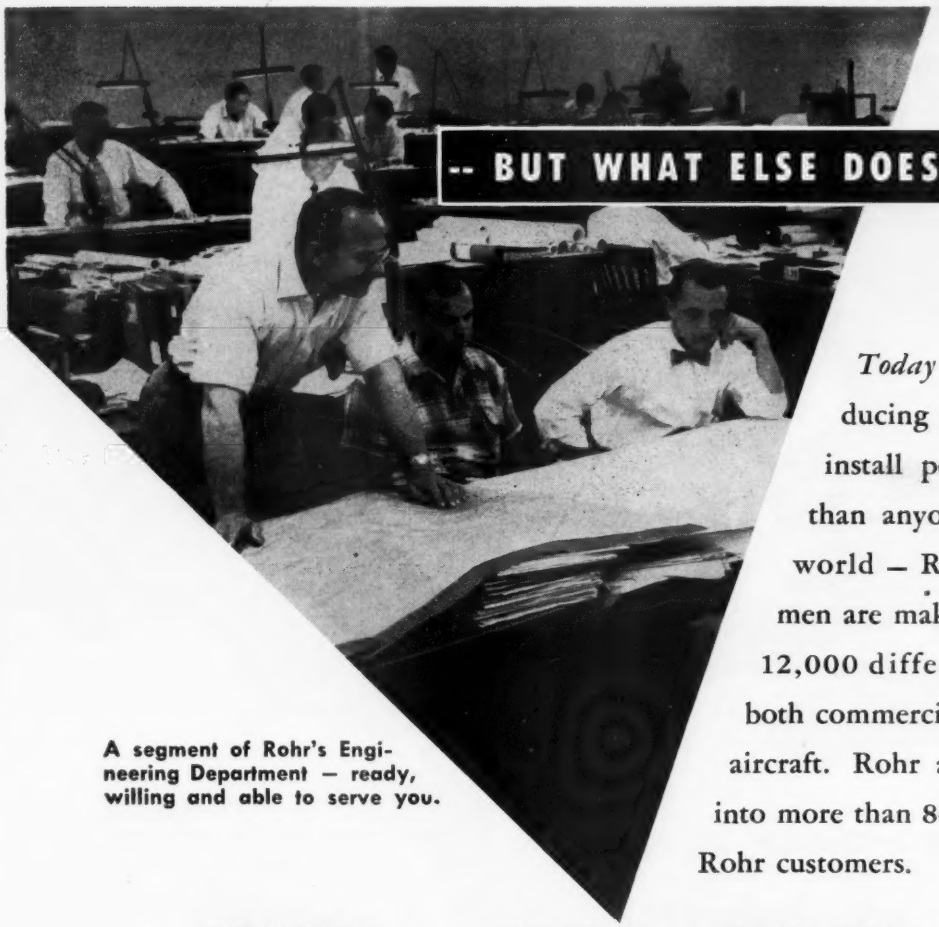

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Aerodynamics (2)

BOUNDARY LAYER & THERMOAERODYNAMICS

Boundary Layer Theory As Applied to the Design of Low Speed Aerofoil Sections. I. N. K. Walker and R. H. W. Annenberg. *Indian Airman*, 5th Year, No. 11, November, 1951, pp. 16, 17.

The Compressible Boundary Layer. George B. W. Young and Earl Janssen. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 229–236, 288, illus. 19 references.

Solution of the laminar boundary-layer equations in integral form using a mechanical differential analyzer. Variations in flow properties through the boundary layer are obtained for Mach Numbers ranging from incompressible to hypersonic flow values at ambient temperatures of 100°, 400°, and 800°R.

Direct Measurements of Skin Friction. Satish Dhawan. *U.S., N.A.C.A., Technical Note No. 2567*, January, 1952. 60 pp., illus. 26 references.

Measurements of laminar and turbulent boundary layers were obtained in the low-speed range with a device that measures the force exerted on a small movable part of a flat plate; results were compared with those of Blasius and von Kármán. Measurements were also made in high subsonic flow and turbulent skin-friction coefficients were determined up to a Mach Number of about 0.8.

Measurement of Heat Transfer and Skin Friction at Supersonic Speeds; Preliminary Results of Measurements on Flat Plate at Mach Number of 2.5. J. E. Johnson and R. J. Monaghan. *Gt. Brit., Aeronautical Research Council, Current Papers No. 59*, 1951 (April, 1949). 35 pp., illus. 4 references. British Information Services, New York. $1.40.

Estimate of Slip Effect on Compressible Laminar-Boundary-Layer Skin Friction. Harold Mirels. *U.S., N.A.C.A., Technical Note No. 2609*, January, 1952. 22 pp., illus. 14 references.

Analysis of the slip flow boundary condition; development of an approximate solution to Rayleigh's problem for a compressible viscous gas, subject to slip at the wall. The solution is related to the flow past a semi-infinite flat plate.

A New Method of Numerical Integration of the Laminar Boundary-Layer. T. G. Cowling. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2575*, 1951 (May 23, 1945). 14 pp., illus. 8 references. British Information Services, New York. $1.00.

A numerical integration procedure that is based on the fact that the equations of steady flow are special cases of the equations of general motion; velocity profiles are found at successive sections across the boundary layer. The method, which resembles Southwell's relaxation technique, is applied to two cases that were solved by Hartree; the amount of numerical work required and the accuracy of the two methods are compared.

An Approximate Solution of Two Flat Plate Boundary-Layer Equations. E. J. Watson and J. H. Preston. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2537*, 1951 (August, 1946). 13 pp., illus. 4 references. British Information Services, New York. $0.90.

Development of a method that leads to a simple analytic approximation for Blasius' solution of the boundary-layer flow past a flat plate. The method is applied to a flat plate in a uniform stream where there is a suction velocity normal to the plate proportional to $x^{-1/2}$, using initial approximations to the velocity of either a constant value or a linear function.

Theory of Turbulent Flow and Its Application to Flow Resistance and Heat Transfer. D. Johnson. (*Teknisk Ukeblad*, Vol. 98, No. 34, September 20, 1951, pp. 675–681.) *Engineers' Digest*, Vol. 13, No. 2, February, 1952, pp. 51–54, illus. 11 references.

A new formula is developed for the velocity distribution in the transition layer in turbulent flow and is used to determine the flow resistance coefficient. This equation is compared with Blasius' and Nikuradse's relations and is valid for Reynolds Numbers from 10^4 to 10^6. An expression is derived for Nusselt Number for use in heat-transfer calculations which is also valid for Prandtl Numbers below 10.

A Preliminary Investigation of a Shockwave-Turbulent Boundary Layer Interaction. S. M. Bogdonoff and A. H. Solarski. *Princeton University, Aeronautical Engineering Laboratory, Report No. 184*, November 30, 1951. 38 pp. illus. 7 references.

Equipment, procedure, and data obtained from static- and pitot-pressure distribution and schlieren photographs on the

interaction of a pressure ratio 2.09 shock wave with a turbulent boundary layer on a flat wall at $M = 2.97$.

CONTROL SURFACES

Readers' Forum: Discussion on "Horizontal Tail Loads in Abrupt Pull-Ups from Level Flight" by I. L. Decker. Bernard Etkin. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, p. 283. 7 references.

FLUID MECHANICS & AERODYNAMIC THEORY

On Supersonic Flow Past a Slightly Yawed Cone. II. A. H. Stone. *Journal of Mathematics and Physics*, Vol. 30, No. 4, January, 1952, pp. 200–213. 5 references.

Analysis of the flow produced by a circular cone, of not too blunt a nose angle, moving at supersonic speed and at a small angle of yaw; determination of the second-order effects of the yaw on the shock-wave configuration; effect of the yaw on the head drag.

Readers' Forum: On the Flow Around a Rotating Disc in a Uniform Stream. Arthur N. Tifford and Sheng To Chu. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 284, 285, illus. 8 references.

Numerical results of exact mathematical analysis. Values are tabulated for the corrected frictional moment coefficients as a function of the relative fluid and disc motion, and of the corrected radial shearing stress coefficient as a function of the relative fluid and disc motions.

Readers' Forum: Slender Body Theory for Supersonic Unsteady Flow. John W. Miles. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 280, 281. 4 references.

Experiments on Interaction of Shock Waves and Cylindrical Bodies at Supersonic Speeds. M. V. Morkovin, E. Migotsky, N. E. Bailey, and R. E. Phinney. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 237–248, illus. 21 references.

Results of an investigation in the University of Michigan Supersonic Wind Tunnel at $M = 1.90$ of three-dimensional shock reflections for a plane shock wave impinging on a cylinder.

The Propagation in a Compressible Fluid of Finite Oblique Disturbances with Energy Exchange and Change of State. Frederick W. Ross. *Journal of Applied Physics*, Vol. 22, No. 12, December, 1951, pp. 1414–1421, illus. 5 references.

Derivation of a theory for oblique waves of finite amplitude which includes the conditions of heat or energy exchange, the transfer of part of the mass to the incompressible state, and finite change in specific heat ratios with the disturbance.

Readers' Forum: On the Speed of Sound in Gases. Irvine I. Glass. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 286, 287, illus. 8 references.

Theoretical and experimental analysis of the propagation of a centered rarefaction wave through gas. Values are obtained from the head of the rarefaction wave for the speed of sound at 0°C. in air, argon, and carbon dioxide.

Shock-Tube Studies of Transonic Flow over Wedge Profiles. Wayland Griffiths. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 249–257, 264, illus. 23 references. Shock-tube studies of the steady flow around two-dimensional wedges over a Mach Number range of 0.85 to 1.80.

A Study of Transonic Gas Dynamics by the Hydraulic Analogy. E. V. Laitone. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 265–272, illus. 10 references.

Spectrum of Turbulence in a Contracting Stream. H. S. Ribner and M. Tucker. *U.S., N.A.C.A., Technical Note No. 2606*, January, 1952. 54 pp., illus. 12 references.

Analysis, using the spectrum concept, of the selective effect of a stream contraction on the lateral and longitudinal turbulent velocity fluctuations of the stream, assuming negligible decay; study of the changes in the spectrum of turbulence due to the restrictive assumption of negligible decay.

INTERNAL FLOW

A Method of Designing Corner Channels and Cascades on a Hyperbolic Base-Line. R. J. Monaghan. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2464*, 1951 (January, 1946). 10 pp., illus. 3 references. British Information Services, New York. $0.75.

Presentation of a design method for two-dimensional corner channels. Two streamlines of a specified flow pattern are chosen as boundaries of a corner channel. Placing a number of similar channels that have suitable velocity distributions side-by-side with their outer streamlines meeting at infinity in each direction results in a closed airfoil section between each pair; the overall result is a cascade of airfoils. This design method emphasizes the flow conditions in the channels between the airfoils, rather than on the airfoils themselves. Construction of a cascade for spinner-driven engine cooling fans illustrates the method.

Readers' Forum: Secondary Flow in Cascades. Hsuan Yeh. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 479, 480, illus. 4 references. Development of a solution for the secondary flow in cascades from vorticity considerations.

Contra-Flow Turbo-Compressor Tests. A. D. Baxter. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2607*, 1951 (June, 1942). 42 pp., illus. 3 references. British Information Services, New York. $2.65.

Several methods of constructing contra-flow compressor wheels were investigated by mechanical tests on single-stage wheels. The results were incorporated in a complete turbo-compressor unit, the performance characteristics of which were then studied.

One-Dimensional Compressible Flow in Vaneless Diffusers of Radial- and Mixed-Flow Centrifugal Compressors, Including Effects of Friction, Heat Transfer, and Area Change. John D. Stanitz. *U.S., N.A.C.A., Technical Note No. 2610*, January, 1952. 61 pp., illus. 8 references.

Development of an analysis method that determines variations in fluid properties as a function of radius for a prescribed variation in diffuser-wall spacing with radius, and of a design method that determines the variation in effective diffuser-wall spacing as a function of radius for an arbitrary prescribed variation in one fluid property.

Nondimensional Compressor Performance for a Range of Mach Numbers and Molecular Weights. H. E. Sheets. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 1, January, 1952, pp. 93–102, illus. 7 references.

A General Theory of Three-Dimensional Flow in Subsonic and Supersonic Turbomachines of Axial-, Radial-, and Mixed-Flow Types. Chung-Hua Wu. *U.S., N.A.C.A., Technical Note No. 2604*, January, 1952. 93 pp., illus. 47 references.

Development of a general theory of steady three-dimensional flow in subsonic and supersonic turbomachines of axial-, radial-, and mixed-flow types for a finite number of blades of finite thickness. The theory considers both the direct and inverse problems and is applicable to either irrotational or rotational absolute flow at the inlet of a blade row at both design and off-design operations.

A Theoretical and Experimental Investigation of the Flow in a Duct of Varying Cross-Section, with Particular Application to the Design of Ducts for Free-Flight Ground-Launched Model Tests. C. H. E. Warren, R. E. Dudley, and P. J. Herbert. *Gt. Brit., Aeronautical Research Council, Current Papers No. 60*, 1951 (August, 1950). 37 pp., illus., tables. 7 references. British Information Services, New York. $1.60.

Design theory, based on an extension of the work of Young and Winterbottom to a duct of varying cross-section, of a duct that represents accurately the internal flow in a jet engine of an aircraft for free-flight ground-launched model tests. This theory, supplemented by wind-tunnel tests, gives the flow characteristics for the duct in the transonic range of forward speeds, and the associated internal drag.

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Wind-Tunnel Investigation of the Contribution of a Vertical Tail to the Directional Stability of a Fighter-Type Airplane. Alfred A. Marino and N. Mastrocola. (*U.S., N.A.C.A., Research Memorandum No. L7K03*, 1948). *U.S., N.A.C.A., Technical Note No. 2488*, January, 1952. 41 pp., illus. 4 references.

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Some Observations on Sharp-Nosed Profiles at Supersonic Speed. J. Valensi and F. W. Pruden. (*International Congress of Applied Mechanics, 6, Paris*, September 22–29, 1946.) *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2482*, 1951 (May 12, 1947). 17 pp., illus. 1 reference. British Information Services, New York. $1.15. Schlieren photographs and pressure measurements on wedge and double-wedge airfoil sections, each with a nose semiangle of 3.6°, at $M = 1.4$; comparison with exact inviscid theory.

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The Supersonic Pressure Drag of a Swept Wing with a Cranked Maximum Thickness Line. K. D. Thomson. *Gt. Brit., Aeronautical Research Council, Current Papers No. 61*, 1951 (June, 1950). 37 pp., illus. 5 references. British Information Services, New York. $1.80.

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I. Development of a method for calculating the ideal theoretical drag of an airfoil which arises from an entropy increase through a limited shock wave. II. Extension to cover the use of the von Kármán-Tsien solution in place of the Glauert relation. The drag rise can be calculated from the theoretical critical Mach Number and the geometric curvature of the surface at the point of maximum suction.

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The Theoretical Lift and Pitching Moment of a Highly Swept Delta Wing on a Body of Elliptic Cross-Section. T. Nonweiler. *Gt. Brit., Aeronautical Research Council, Current Papers No. 58*, 1951 (June, 1950). 14 pp., illus., folding chart. 2 references. British Information Services, New York. $0.90.

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Fundamental ideas and mathematical techniques that form the basis of current methods for calculating the stability and response of aircraft. The transient characteristics and steady-state response of the aircraft are obtained by using the Transfer Function

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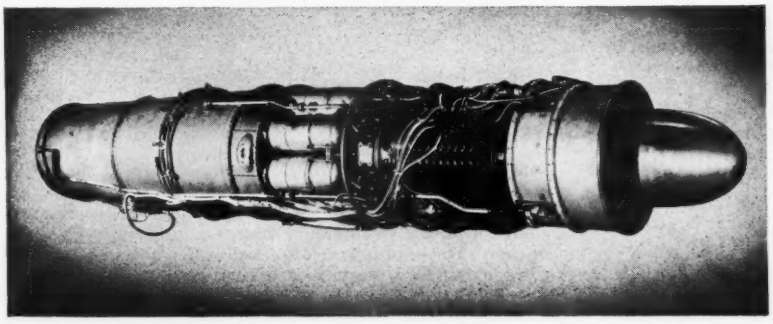

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Fourier concept. The analysis is applied first to obtaining the stability and response characteristics of a rigid aircraft, and then extended to an automatically controlled elastic aircraft.

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Aircraft in Agriculture. P. H. Southwell. *Royal Aeronautical Society, Journal*, Vol. 56, No. 493, January, 1952, pp. 33–46, illus. 5 references. Performance requirements, techniques, spraying and dusting equipment, and types of aircraft for agricultural uses.

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de Havilland D.H. 106 Comet-Engined Turbojet Transport Aircraft, England. *de Havilland Gazette*, No. 67, February, 1952, pp. 4, 5, illus. Underwing refuelling system.

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DEVELOPMENT TESTING

Non-Flying Prototype. *Flight*, Vol. 61, No. 2250, March 7, 1952, pp. 268–271, illus.

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An Impulse-Momentum Method for Calculating Landing-Gear Contact Conditions in Eccentric Landings. Robert T. Yntema and Benjamin Milwitzky. *U.S., N.A.C.A., Technical Note No. 2596*, January, 1952. 60 pp., illus. 5 references.

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Development of a method of calculating the load distribution on the wheels of a bogie undercarriage and its variants in all land-

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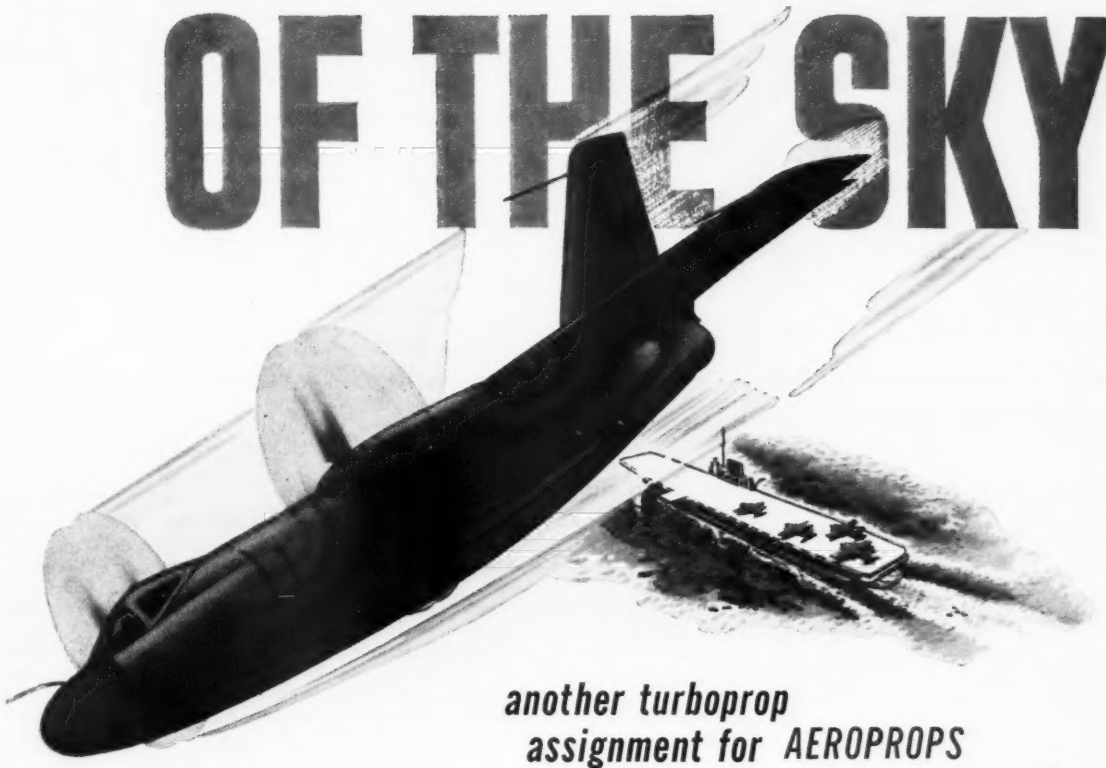

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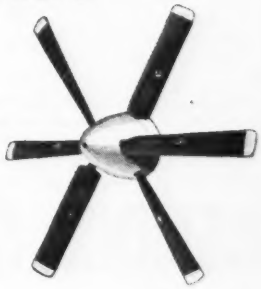

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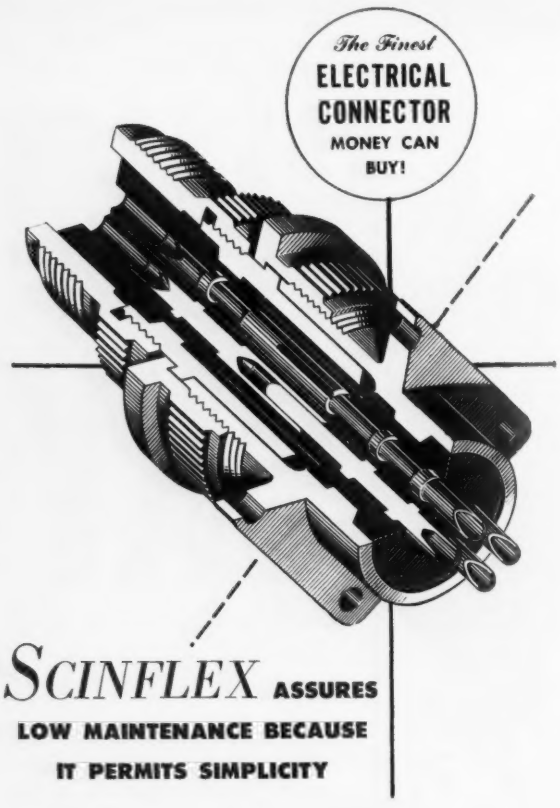

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Prevention of Castor Shimmy by the Twin-Contact Tyre. O. J. Marstrand. **Appendix I—Comparative Shimmy Trials of Twin Contact (T.C.) and Other Tyres.** J. B. Shearlaw. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2508*, 1951 (March, 1942). 15 pp., illus. 1 reference. British Information Services, New York. $1.00.

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A mathematical and graphic analysis of the visibility distribution of the slope-line approach-light system using the 250 PAR lamp and the 400-watt, 115-volt lamp. The distance from which a slope-line light can be seen by pilots and that from which it appears excessively glaring are determined under a variety of daytime and nighttime visibility conditions and lamp brightness settings.

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After Effects of Intermittent Positive Radial Acceleration. R. C. Wilson, G. L. Bryan, G. A. Green, N. E. Willmorth, A. A. Canfield, and N. D. Warren. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 509–517. 16 references.

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Noise Problems Associated with Aircraft Maintenance. Horace O. Parrack and Donald H. Eldredge. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 470–476, illus. 4 references.

Data on sound distribution around some U.S. Air Force aircraft and its effects on the hearing and efficiency of aircraft-maintenance and line-operations personnel, comparison of the advantages and disadvantages of various types of ear protectors.

Recent Navy Aero-Medical Equipment Developments. M. D. Courtney. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 540–543.

New developments in protective equipment for pilots of high-performance aircraft which include helmets and flying suits, improved bail-out devices and techniques, and oxygen equipment.

Visual and Orthopedic Defects in Civil Airmen. D. M. Gilford and W. R. Stovall. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 442–455, 558, illus.

Personality Research in Naval Aviation Selection. Joseph F. Snyder. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 530–534, 553, illus.

Computers & Simulators

Resistance Wire Computing Device for Solving Algebraic Equations. C. V. Ramamoorthy and W. W. Soroka. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 134–137, illus.

Construction, operation, and power supplies of a computer that solves simultaneous equations. The computer consists of potentiometer networks for obtaining the product of two or more factors and resistor circuits for adding several factors. Operation of the computer is demonstrated by the solution of a problem in vibration isolation in which coupling exists between translation and rotation.

The Design of Circuits Using Electro-Mechanical Devices. R. A. Brooker. *Journal of Scientific Instruments*, Vol. 29, No. 2, February, 1952, pp. 45–50, illus. 2 references.

Circuit problems that were encountered in the design of auxiliary electromechanical equipment used with the Edsac (Electronic Delay Storage Automatic Calculator) at the University Mathematical Laboratory, Cambridge.

On the Background of Pulse-Coded Computors. II. T. J. Rey. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 66–69, illus. 3 references. The mathematical and arithmetical logic of digital computers; arithmetical operation; comparison of digital and analog systems.

Electrical Pressure Integrator. Arleigh P. Helfer. *U.S., N.A.C.A., Technical Note No. 267*, January, 1952. 44 pp., illus.

Design of a computer, utilizing a group of electrical strain gages, which integrates airfoil pressures into a quantity representing the normal force and pitching moment acting on the airfoil, divides the output of dynamic pressure q, and yields normal-force and moment coefficients c_n and c_m without manual integrations of manometer data; circuit diagrams; comparison of weighting methods.

An Electronic Multiplier. M. J. Somerville. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 78–80, illus. Circuits and operation of a multiplier with a negligible time lag for use in an analog computer; arrangement for solving Airey's equation.

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Operation of an electric network analyzer of ladder construction, in which displacement is represented by node-pair voltages and moments by currents; applications to analyses of beams, beam-columns, and columns.

Components for Computing Machinery. John D. Goodell. *Radio & Television News*, Vol. 47, No. 2, February, 1952, *Radio-Electronic Engineering*, pp. 6–8, 27, 28, illus. Comparison of characteristics, reliability, and consequences of failure of components made of magnetic and other dielectric materials with components in which vacuum tubes are used.

R-F Bursts Actuate Gas-Tube Switch. H. J. Geisler. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 104, 105, illus.

A technique in which simple gas diodes are activated by bursts from pulsed radio-frequency oscillators and used as switches in storage, accumulator, and other electronic-computer circuits, permitting operating speeds up to 100,000 pulses per sec.

Electron Tube Experience in Computing Equipment. J. A. Goetz and A. W. Brooke. *Electrical Engineering*, Vol. 71, No. 2, February, 1952, pp. 154–157, illus.

Regulated 1,600-Ampere Filament Supply. A. W. Vance and C. C. Shumard. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 122, 123, illus. Diagram and operation of the circuit that regulates the filament voltage in Project Typhoon's analog-digital computer.

A Multi-Voltage Universal Motor. A. Novazzotti. (*Marelli Review*, Vol. 24, No. 1-12, 1950, pp. 24–27.) *Engineers' Digest*, Vol. 13, No. 2, February, 1952, pp. 41, 42, illus.

Circuits and operation of a motor for calculating machines that can work on 110, 160, 220, or 280 volts at frequencies of 42, 50, and 60 cycles per sec., and on d.c.

An Electronic Servo Simulator. N. T. van der Walt. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 52–57, illus. 4 references.

Design, operation, and circuits. The simulator responds to a repetitive step input and is made up of a number of units in cascade each of which has a feedback amplifier and represents a first order transfer function. A clamping arrangement enables unstable, highly undamped closed-loop and certain open-loop arrangements to be portrayed directly on a cathode-ray oscilloscope with a synchronous time base.

Electronics (3)

Heat-Transfer Design Problems in Aircraft Electronic Equipment. Leonhard Katz. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 61–68, 81, illus.

Basic principles of heat-transfer in electronic equipment that is installed in aircraft operating at high altitudes. Analysis and solution of two heat-transfer problems: the design of electronic equipment and its cooling system to permit the equipment to operate efficiently at high altitudes, and the reduction in weight of the overall electronic equipment in an aircraft; the turbulent air cooling plate.

ANTENNAS

General Theory of Electromagnetic Horns. A. F. Stevenson. *Journal of Applied Physics*, Vol. 22, No. 12, December, 1951, pp. 1447–1460, illus. 6 references. Development of a general theory applicable to the propagation of electromagnetic waves in perfectly conducting horns of arbitrary shape.

Mutual Coupling of a Slot with a Dipole Antenna. Walter J. Surtees. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 208–211, illus. 11 references.

Design Limitations on Aircraft Antenna Systems. J. V. N. Granger. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 82–87, illus.

Microwave Antenna Pattern Plotter. John W. Tilley. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 130–132, illus. 2 references.

Development, design, and operation of a compact automatic antenna pattern recorder that furnishes a complete pattern in two minutes; circuit diagrams. Antenna platform and recording drum are turned in synchronism; a detector-amplifier servosystem drives the recording pen.

CIRCUITS & COMPONENTS

A Critical Study of the Circuit Concept. Jesse Gerald Chaney. *Journal of Applied Physics*, Vol. 22, No. 12, December, 1951, pp. 1429–1436, illus. 4 references.

Broad-Banding by Stagger Tuning. Roland C. Wittenberg. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 118–121, illus. 5 references.

Nomographs and charts for simplifying design calculations of the Butterworth or Tschebycheff stagger-tuned intermediate-frequency response amplifiers; bandwidths up to twice the center frequency and 2-pole to 4-pole staggers are provided for.

Dual Circuit of a Feedback Amplifier. D. A. Bell. *Wireless Engineer*, Vol. 29, No. 341, February, 1952, pp. 40–43, illus. 3 references.

Inexpensive Square-Wave Generator. G. W. Gray. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 101–103, illus.

Circuits and operation of a low-cost generator with a cathode-controlled multivibrator that has three tube envelopes and gives square waves from 50 cycles per sec. to 1 mc. with 2-per cent tilt in the negative half. An additional circuit is presented in which a pair of pentodes replaces the cathode resistors to produce square waves and which provides for synchronizing.

A Frequency Controller for Reflex Klystrons. Edward S. Dayhoff. *Review of Scientific Instruments*, Vol. 22, No. 12, December, 1951, pp. 1025, 1026, illus. 1 reference.

Oscillograph Beam Intensification. *Radio & Television News*, Vol. 47, No. 2, February, 1952, *Radio-Electronic Engineering*, pp. 19, 26, illus.

A technique of intensifying the electron beam of a high-voltage oscillograph that increases writing speed to $^3/_4$ the velocity of light for the study of rapidly varying electric surges and the insulation breakdowns they produce; circuit diagrams.

Retarding-Field Oscillators. J. J. Ebers. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 138–145, illus. 6 references.

Analysis of the electron mechanisms involved in the energy conversions responsible for pendulum and velocity-variation types of oscillations in retarding-field oscillators; the processes of bunching; drifting and working of electrons; comparison with a reflex klystron; possible applications of the electron mechanisms to wide-range, high-frequency generators in the 3,000–30,000-mc. range.

Line-Terminated Pulse Stretcher. L. Reifel and G. M. Burgwald. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 186, 190, 194, illus. 1 reference. Circuit and operation of an instrument that can stretch pulses by a factor of 1,000 in a single step.

Composite Ladder Filters; Second-Order Image Impedances. R. O. Rowlands. *Wireless Engineer*, Vol. 29, No. 241, February, 1952, pp. 50–55, illus. 1 reference.

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High Temperature Metallized-Paper Capacitors. *Aerovox Research Worker*, Vol. 22, No. 1 and 2, January-February, 1952, pp. 1–5, illus. 16 references. Comparison of the properties of Aerolene with those of other impregnants for metallized paper capacitors operating at temperatures above 70°C.

The Wire Capacitor and Other Composite Drawn Products. J. L. H. Jonker and P. W. Haaijman. *Philips Technical Review*, Vol. 13, No. 6, December, 1951, pp. 145–151, illus. 1 reference.

Properties, methods of producing, and applications of a wire capacitor with a total volume of 30 mm. or less and of other small composite drawn components for electronic equipment of limited dimensions.

Piezo-Electric Crystal Constants. W. R. Hinton. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 76, 77, illus. 4 references.

Circuit and construction of a balanced measuring transformer that measures the effective series resistance of a crystal. A method is also presented for measuring effective series reactance and, therefore, the Q, by allowing the crystal to control the frequency of an oscillator.

Resistors at Radio Frequency. T. J. F. Pavlasek and F. S. Howes. *Wireless Engineer*, Vol. 29, No. 341, February, 1952, pp. 31–36, illus. 15 references.

Investigation, over a frequency range of 500 kc. to 40 mc. of the radio-frequency resistance and equivalent shunt capacitance of JAN-R-11 type, fixed-composition resistors ranging from 1,000 ohms to 2 megohms.

COMMUNICATIONS

Pictorial Radio. I, II. C. D. Tuska. *Franklin Institute, Journal*, Vol. 253, Nos. 1, 2, January, February, 1952, pp. 1–20; 95–124, illus. 37 references.

I. Historical background of the development of multicoordinate or graphic indicating radio systems for obtaining two- or three-dimensional information transmitted or reflected from a number of geometrically related points. Emphasis is placed upon radio vision systems, such as Plan Position Indicating Radar (PPI), which display the received information in graphic form along two or more coordinates. II. Review of the design and performance details of various radio-vision locating systems and sounding devices; development of wartime and postwar marine and aviation radar systems.

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CONSTRUCTION TECHNIQUES

Paper Containers Cut Potting Costs. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 248, 252, 256, illus. Method and economic advantages of using paper containers instead of iron mixing and pouring pots in the potting of electronic components.

Fast Construction of Temporary Circuits. Arthur R. Jubenville. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 178, 182, 186, illus. Design of a Jiffy Clip that can connect up to seven conductors to a given terminal; techniques and equipment for the construction of temporary circuits.

ELECTRONIC CONTROLS

Single-Knob Adjustment of Reset Rate and Gain. W. I. Caldwell. *Instruments*, Vol. 25, No. 2, February, 1952, pp. 196–200, illus.

Properties of a circuit for a proportional plus automatic-reset controller in which the reset rate and proportional bandwidth are both changed by adjustment of the opening of a single needle valve; effect of these responses on circuit and controller stability.

Control System for Induction Heaters. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 194, 198, 202, illus.

Design, components, and operation of a control system that reduces the power when the desired temperature has been reached and that disconnects the power when the brazing is completed, for brazing near rubber or plastic insulation.

Electronic Fuze Research. R. L. Eichberg. *Ordnance*, Vol. 36, No. 191, March-April, 1952, pp. 839–841, illus. Work of the Ordnance Division of the National Bureau of Standards on the proximity fuse.

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Trustworthy Valves; Greater Reliability Achieved by Improved Mechanical Design. E. G. Rowe. *Wireless World*, Vol. 58, No. 3, March, 1952, pp. 105–108, illus.

Oxide Cathode Life. *Wireless World*, Vol. 58, No. 2, February, 1952, p. 76. 2 references. Results of a study of possible causes of loss of emission in oxide cathode tubes.

The Influence of the Core Material on the Thermionic Emission of Oxide Cathodes. H. A. Poehler. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 190–196, illus. 30 references.

Electron Tube Experience in Computing Equipment. J. A. Goetz and A. W. Brooke. *Electrical Engineering*, Vol. 71, No. 2, February, 1952, pp. 154–157, illus.

Equipment and methods used by the International Business Machines Corp. in the preventive maintenance testing of tubes for a computer before installation. Data are presented for the rate of tube failures as a function of type, the common causes of tube failures, and on the life expectancy and survival of tubes.

The Single-Pulse Dekatron. J. R. Acton. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 48–51, illus. 1 reference.

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Crystal Diodes in Modern Electronics. V. David T. Armstrong. *Radio & Television News*, Vol. 47, No. 2, February, 1952.

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The stability of periodic solutions of the general forced Duffing equations with and without damping and of the general forced van der Pol equation is determined by setting the conditions required for periodic solutions of the corresponding variational equation; application to the forced vibrations of a triode oscillator with a fifth-order tube characteristic.

MEASUREMENTS & TESTING

Valve Voltmeter; The Rectifier Section. M. G. Scroggie. *Wireless World*, Vol. 58, No. 3, March, 1952, pp. 89–94, illus. 2 references. Design of input circuits for alternating voltage measurement.

The *Q* of a Microwave Cavity by Comparison with a Calibrated High-Frequency Circuit. Hugh LeCaine. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 155–157, illus. 2 references.

Development of a method of measuring cavity *Q* at microwave frequencies in which a two-channel superheterodyne technique is used; advantages of the method; application to the measurement of cavity shunt resistance.

A Note on Performance Parameters of Voltage Stabilizers. J. J. Gilvarry and D. F. Rutland. *Review of Scientific Instruments*, Vol. 22, No. 12, December, 1951, pp. 1021, 1022. 2 references. Analytic expressions for evaluating performance parameters.

A Bridge Circuit for Wire Resistance Strain Gauges. B. V. Hamon. *Journal of Scientific Instruments*, Vol. 29, No. 2, February, 1952, pp. 53, 54, illus. 2 references.

A strain-gage bridge circuit in which Wardner-Wolff adjustable resistance elements are used in the measuring arm rather than the usual slide-wire measuring element.

Shaft-Bearing Clearances Measured by Mutual Inductance. *U.S., Central Air Documents Office (Army-Navy-Air Force), Technical Data Digest*, Vol. 17, No. 2, February, 1952, pp. 7, 8, illus.

A method of measuring clearances between shafts and sleeve or journal bearings in the study of engine and engine lubricants. The method employs a mutual-inductance type of electrical distance-measuring element and does not interrupt engine operation at high speeds.

Vibrating-Plate Viscometer. J. G. Woodward. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 98–100, illus. 5 references.

Construction, performance, and circuits of a direct-reading vibrating-plate viscometer with a range of 0.1 to 100,000 and accuracy within ±5 per cent. An electromechanical transducer measures the viscous damping exerted on the plate by the liquid.

Portable Electronic Weighing Kit. *Aviation Age*, Vol. 17, No. 2, February, 1952, pp. 29, 30, illus.

Construction and advantages of the Cox & Stevens Aircraft Corp. CS-7 portable electronic weighing kits for aircraft weighing with capacities ranging from 150,000 lbs. to 800,000 lbs.

An Electronic Flip-Flop As a Machine Element. John B. Flynn. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 124–129, illus.

Applications of electronic counters as measurement or control devices; mechanical analogy of the electronic flip-flop method of counting; components and circuits of the counters. Block diagrams show arrangement of elements for counting, sorting, and weighing applications.

NAVIGATION AIDS

How Airport Surface Detection Operates. *American Aviation*, Vol. 15, No. 42, March 31, 1952, p. 14, illus.

Factual data on the U.S.A.F. Airport Surface Detection Equipment that uses radar to sweep the airport 60 times per min. and presents a continuous, changing picture of airport conditions.

Search Radar for Civil Aircraft. *Flight*, Vol. 61, No. 2249, February 29, 1952, p. 245. Results of operational tests on the use of radar equipment in civil aircraft.

The All-Weather Program As Affected by Design of Electronic Equipment. Milton W. Arnold. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 55, 56.

Radio for Gliders; A Survey of the Present Situation. Robert H. Ball. *Soaring*, Vol. 16, No. 1, January-February, 1952, pp. 6–9, 20.

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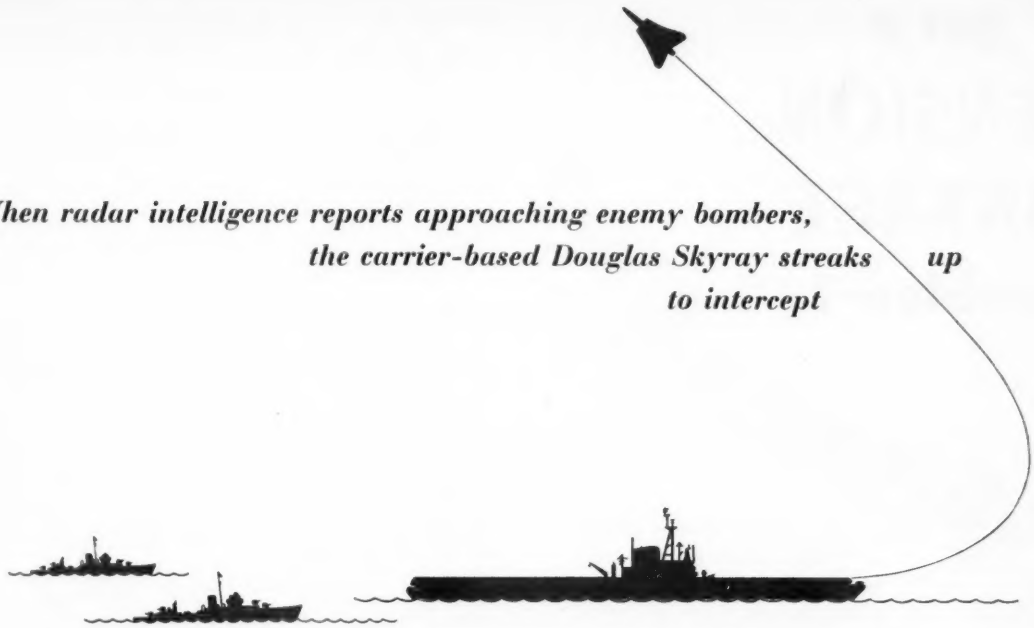
A Statistical Approach to the Measurement of Atmospheric Noise. Robert S. Hoff and Raymond C. Johnson. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 185–187, illus. 7 references.

Random Noise; Rate of Occurrence of Peaks. V. J. Francis. *Wireless Engineer*, Vol. 29, No. 341, February, 1952, pp. 37–40, illus. 4 references.



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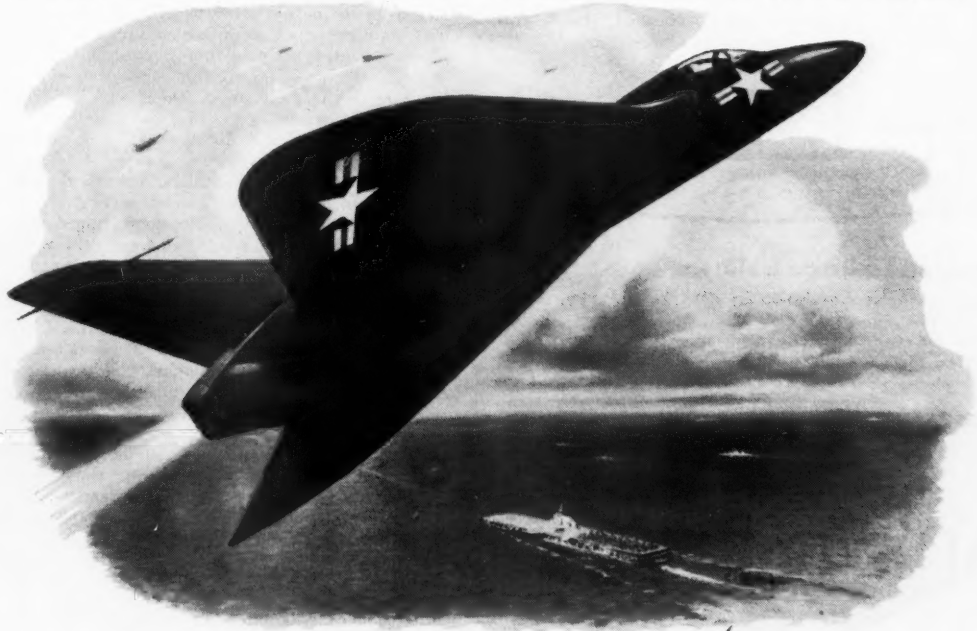

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RADAR

Origins of Radar. *Wireless World*, Vol. 58, No. 3, March, 1952, pp. 95–100.

Review of radar development in Great Britain; principles and devices that formed the bases of successful claims from the (British) Royal Commission on Awards to Inventors, together with a list of claimants, their claims, and awards received.

Radomes and Aircraft Design. Ernest W. Schlieben. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 69–81. illus. 5 references. Effects of radomes on radar performance and aircraft systems performance; radome design criteria; aerodynamic and structural considerations.

SATURABLE REACTORS

Magnetic Modulators. E. P. Felch, V. E. Legg, and F. G. Merrill. *Electronics*, Vol. 25, No. 2, February, 1952, pp. 113–117, illus. 13 references.

Circuit design and operation of a magnetic modulator that converts low-level, low-frequency, or d.c. signals into a.c. signals that can be amplified by conventional methods.

TRANSMISSION LINES

Measurements of Wavelengths and Attenuation in Dielectric Waveguides for Lower Modes. C. W. Horton and C. M. McKinney. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 177–180, illus. 15 references.

Measurements of the wave lengths of waves guided by polystyrene, lucite, textolite, and paraffin rods and by plastic tubes filled with Nujol and dioxane, for the TE_{0n}, TM_{0n}, HE_{1n}, and EH_{1n} modes for $n = 1, 2$; comparison with solutions of the characteristic equation.

Compilation of the Propagation Constants of an Inhomogeneously Filled Waveguide. Ll. G. Chambers. *British Journal of Applied Physics*, Vol. 3, No. 1, January, 1952, pp. 19–21. 4 references. The propagation constants of an inhomogeneously filled wave guide are calculated, using the Rayleigh-Ritz method of finding frequencies of vibration of a mechanical system.

Distortion of a Frequency-Modulated Signal by Small Loss and Phase Variations. F. Assadourian. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 172–176, illus. 2 references.

Derivation of general formulas for the harmonic and total distortion in the output frequencies of linear transmission systems with pure frequency-modulated inputs and with amplitude and phase characteristics involving wiggles; sinusoidal representation of amplitude and phase wiggles; application of the general distortion formulas to wave guides loaded with pure resistances; construction of distortion graphs for wave guides.

Circular Wave Guide Attenuation. *Radio & Television News*, Vol. 47, No. 2, February, 1952, *Radio-Electronic Engineering*, p. 32. A nomograph for determining the attenuation of the $TM_{1,1}$ (E_1) mode in a circular air-dielectric wave guide.

Shorted Stubs of High Resonant Impedance. Joseph M. Diamond. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 188, 189, illus. 2 references.

Curves that specify the parameters of a coaxial or twin-line shorted stub of maximum resonant impedance when the frequency, outer dimension, and lumped capacitance at the open end are known.

The Short-Slot Hybrid Junction. Henry J. Riblet. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 180–184, illus. 13 references.

Theory, performance, and applications of a high-performance x-band hybrid junction that consists of a suitably loaded gap in the narrow common wall between two $\frac{1}{2}$- by 1-in. wave guides.

Cavity Resonator Regarded As a Transmission Line. G. W. O. Howe. *Wireless Engineer*, Vol. 29, No. 241, February, 1952, pp. 29, 30, illus. 2 references.

WAVE PROPAGATION

Atmospheric Absorption Chart. Arnold Shostak. *Electronics*, Vol. 25, No. 2, February, 1952, p. 134, illus.

An analysis and chart of the effect of path length, water vapor content, and oxygen content on the degree of absorption of a propagated electro-magnetic wave by the atmosphere.

On the Convergence of Approximate Solutions of the Wave Equation to the Exact Solution. Werner Leutert and George G.

O'Brien. *Journal of Mathematics and Physics*, Vol. 30, No. 4, January, 1952, pp. 252–256. 2 references.

Equipment

Power Controls for Aircraft. C. F. Joy. *Royal Aeronautical Society, Journal*, Vol. 56, No. 493, January, 1952, pp. 7–24, illus. 11 references.

Analysis of the design and operation of electrical, hydraulic, and pneumatic power-control systems, of piston-jack, screw-jack, and screw-roller-jack actuators, and of other control-system components; technical and economic factors involved in selecting power-controls for aircraft. A table gives data on the weights of 8 types of power-control systems.

Vibration Isolator. J. S. Zimmer. *Machine Design*, Vol. 24, No. 2, February, 1952, pp. 132–135, illus.

A center-of-gravity vibration isolation mount for uniform protection for precision instruments used in aircraft regardless of flight position, as developed by General Electric Co.

HYDRAULIC & PNEUMATIC (20)

A Nonflammable Hydraulic Fluid. Beverly A. Dodge. *Hydraulic Engineer*, Vol. 1, No. 5, December-January, 1951–52, pp. 6, 7, illus. Requirements for nonflammable hydraulic fluids; properties of Carbide and Carbon Chemicals Co.'s Ucon hydrolubes.

Fluids for Hydraulic Systems; Basic Types and Where to Use Them. Kenneth Rose. *Materials & Methods*, Vol. 35, No. 1, January, 1952, pp. 100–102, illus.

Many Automotive and Aviation Uses for Hydraulic Fluids. *Automotive Industries*, Vol. 106, No. 5, March 1, 1952, pp. 50, 66, illus. Composition of hydraulic fluids; requirements for and guides to the nonflammability of such fluids for aircraft use.

High Pressure Hydraulics. *Aeronautics*, Vol. 26, No. 1, February, 1952, pp. 46, 47, illus. Development, design, and operation of an aircraft hydraulic system that works at 4,000 lbs. per sq.in., by the British Messier Co.

Predicting Rotary Air Motor Performance. E. T. Kisselburg and W. F. McCombs. *Applied Hydraulics*, Vol. 5, No. 2, February, 1952, pp. 42, 44, 46, 47, illus.

A method of predicting the performance of rotary air motors which is based on equations for evaluating the continuous flow process. Theoretical performance curves are developed for a frictionless motor of the Lear Romec RD 7440A type.

Applied Hydraulics 1952 Directory. *Applied Hydraulics*, Vol. 5, No. 1, January, 1952, pp. 26, 28, 30, 46–192.

Directories of U.S. and of British manufacturers of hydraulic and pneumatic equipment; directories of the hydraulic and pneumatic industrial and aviation products. Indexes are included for the industrial and aircraft products.

Development Trends in Aircraft Hydraulics and Pneumatics. Ralph E. Middleton. *Applied Hydraulics*, Vol. 5, No. 1, January, 1952, pp. 42–44.

Flight Operating Problems (31)

HIGH-ALTITUDE FLIGHT

Meteorology and Jet Aircraft. I, II. *The Aeroplane*, Vol. 82, Nos. 2119, 2120, February 29, March 7, 1952, pp. 234; 285, 286. Problems of flying jet aircraft in clouds above 40,000 ft.

ICE PREVENTION & REMOVAL

Preliminary Investigation of Cyclic De-Icing of an Airfoil Using an External Electric Heater. James P. Lewis and Dean T. Bowden. *U.S., N.A.C.A., Research Memorandum No. E51J30*, February 4, 1952. 43 pp., illus. 12 references.

Equipment, procedure, and results of an investigation conducted in the N.A.C.A. Lewis icing-research tunnel to determine the characteristics and requirements for the cyclic deicing of an NACA 65,2-216 airfoil by an external electric heater of the rubber-clad type mounted on the forward portion of the airfoil. Airspeed was limited to 175 m.p.h.

The Calculated and Measured Performance Characteristics of a Heated-Wire Liquid-Water-Content Meter for Measuring Icing Severity. Carr B. Neel, Jr., and Charles P. Steinmetz. *U.S., N.A.C.A., Technical Note No. 2615*, January, 1952. 59 pp., illus. 16 references.

Design and performance characteristics of a meter for obtaining statistical flight data on the liquid-water content of icing clouds and for directly indicating icing severity. The sensing element of the meter is a wire of known temperature-resistance characteristics which is heated by passing electrical current through it and is mounted in the air stream.

De-Icing of Gas-Turbine Engines. L. H. Hayward. *The Aeroplane*, Vol. 82, No. 2119, February 29, 1952, pp. 243, 246, illus. Review of recently patented British gas-turbine deicing devices and their method of operation.

NOISE REDUCTION

A Method for Evaluating Aircraft Acoustical Comfort. Stanley Lippert and Matha M. Miller. *Journal of Aviation Medicine*, Vol. 23, No. 1, February, 1952, pp. 54–66. 7 references.

Graphic standards of acoustical comfort for pilots of turboprop or conventional propeller-driven aircraft are derived from literature containing octave analyses of aircraft noise levels which are accompanied by judgments of comfort. A one-number Acoustical Comfort Index is developed from these standards and is compared to other criteria for comfort, such as the overall noise level.

Noise Muffler Fails to Impress. Scott H. Reiniger. *Aviation Week*, Vol. 56, No. 6, February 11, 1952, pp. 38, 41, 43, illus. Appraisal of Aero Sonic Corp.'s engine noise muffler by major air lines and by C.A.A.; recommendations for an effective noise muffler.

Quieter Argonaut. *Flight*, Vol. 61, No. 2249, February 29, 1952, pp. 242, 243, illus.

Design and operation of the cross-over exhaust system developed for the Merlin T.M.L. power plant by Rolls-Royce, Ltd. and used by B.O.A.C. in all four engines of a Canadair C-4 Argonaut. Redesignated the Merlin T.M.O., the new system reduces noise by exhausting the gases away from the fuselage, by mutual cancellation of many of the harmonic constituents, and by reducing back-pressure.

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Storm and Clear Air Turbulence. A. F. Merewether and F. C. White. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 57–60, illus. 10 references. Turbulence in clouds and clear air turbulence encountered in flight; detection of thunderstorms.

Flight Safety & Rescue (15)

Modern Trends in Civil Airworthiness Requirements. Walter Tye. *Royal Aeronautical Society, Journal*, Vol. 56, No. 494, February, 1952, pp. 73–96, Discussion, pp. 96–108, illus. 7 references.

Performance and structural requirements and trends in safety, airworthiness, and crashworthiness of civil aircraft; comparative accident data for the United Kingdom and the U.S.

Flight Testing (13)

Instrumentation of Aircraft for Flight Testing. B. M. Rimmer. *Aircraft Engineering*, Vol. 24, No. 275, January, 1952, pp. 2–5, 28, illus. 2 references. A review of practical problems associated with the recording of instrument readings in flight.

Fuels & Lubricants (12)

Continuous Fuel Sprays. R. A. Dodge, W. W. Hagerty, J. W. Luecht, J. L. York, D. R. Glass, H. E. Stubs, and R. A. Yagle. *U.S., Air Force, Technical Report No. 6067, Part 2*, November, 1950. 54 pp., illus.

Development of a photographic technique that obtains the mass and velocity distribution of a spray and of an instrument for the rapid analysis of spray; analysis of the combustion performance of nozzles with known spray characteristics and of the effect of spray characteristics on combustion performance; equipment and procedure.

Application of the Phase Behavior of Binary Systems to the Improvement of Combustion. Howard B. Palmer, J. O. Hirschfelder, and Charles A. Boyd. *Wisconsin, University, Naval Research Laboratory, Department of Chemistry, Report No. CM-702*, January 2, 1952. 18 pp., illus. 11 references.

Construction of a simple flow-type apparatus for determining the phase diagrams for fuel mixtures; experimental data for a nitrogen-heptane system. The phase diagram shows liquid-vapor equilibrium as a function of pressure, temperature, and chemical composition.

Catalytic Effect of Several Metals on the Oxidation of Lubricating Oils. D. W. Sawyer. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 1, January, 1952, pp. 113–119, Discussion, pp. 119–122, illus. 10 references. Quantitative data and equipment and procedure for tests of the relative effects of various metals and alloys on the oxidation of mineral lubricating oils.

Quantitative Evaluation of Rocket Propellants. S. S. Penner. *American Journal of Physics*, Vol. 20, No. 1, January, 1952, pp. 26–31, illus. 12 references.

A procedure for the quantitative evaluation of chemicals as rocket propellants, assuming an isentropic adiabatic expansion. Calculations are given for propellant performance for flow without chemical change and for flow which at all times is in thermodynamic equilibrium.

Calculated Data for the Combustion with Liquid Oxygen of Water-Diluted Alcohols and Paraffin in Rocket Motors. I. C. Hutcheon and S. W. Green. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2572*, 1951 (October, 1947). 13 pp., illus. British Information Services, New York. $0.90.

Calculation of the flame composition, combustion temperatures, and specific impulses for the combustion of liquid oxygen and water-diluted methyl alcohol, water-diluted ethyl alcohol, and aviation gas-turbine paraffin at temperatures below 2,700°K., evaluation of the propellant combinations as rocket fuels.

The Effects of Several Variables upon the Ignition Lag of Hypergolic Fuels Oxidized by Nitric Acid. Stanley V. Gunn. *American Rocket Society, Journal*, Vol. 22, No. 1, January-February, 1952, pp. 33–38, illus. 12 references.

Development of a method for measuring the ignition lag of self-igniting (hypergolic) bipropellant combinations; ignition-lag data for combinations of nitric acid with aniline, furfuryl alcohol, and mixtures of aniline and furfuryl alcohol at ignition lags of 10–400 millisec.

Handling Hydrogen Peroxide. A. V. Cleaver. *de Havilland Gazette*, No. 67, February, 1952, pp. 20, 21, illus. Techniques of handling hydrogen peroxide for fueling the de Havilland Sprite rocket motor; ground handling problems due to the nature of the fuel.

Handling Hydrogen Peroxide. *Flight*, Vol. 61, No. 2246, February 8, 1952, p. 155, illus. Properties and techniques of handling and containing hydrogen peroxide used as an oxidant in the de Havilland Sprite A.T.O. unit.

Gliders (35)

Military Gliders of World War II. Harry N. Perl. *Soaring*, Vol. 16, No. 1, January-February, 1952, pp. 12–15, illus. Tables of U.S. and foreign training and troop-carrying gliders.

Avia 40 P Low-Speed High-Performance Sailplane, France. Guy Borgé. *Sailplane and Glider*, Vol. 20, No. 2, February, 1952, pp. 2–4, illus.

KIM-2 Stahanovec Sailplane, U.S.S.R. *Soaring*, Vol. 16, No. 1, January-February, 1952, p. 16, illus.

Oberlerchner Musger-19 Gull-Wing Sailplane, Austria. Hubert Zuerl. *Sailplane and Glider*, Vol. 22, No. 2, February, 1952, p. 4, illus.

Slingsby Type 35 Two-Place and Type 38 Open-Primary Gliders, England. *The Aeroplane*, Vol. 82, No. 2119, February 29, 1952, p. 257, illus.

University of Minnesota UMG III Class I Glider. W. W. Harris. *Soaring*, Vol. 16, No. 1, January-February, 1952, pp. 18, 19, illus.

Radio for Gliders; A Survey of the Present Situation. Robert H. Ball. *Soaring*, Vol. 16, No. 1, January-February, 1952, pp. 6–9, 20.

Jet Assisted Take-Off. Warren J. Merboth. *Sailplane and Glider*, Vol. 20, No. 2, February, 1952, pp. 6, 7, illus. Use of the JATO Junior rocket for glider take-offs. The rocket, built by Aerojet Engineering Corp., has a sea-level static thrust of 250 lbs.

Instruments (9)

Automatic Flight Control. James L. Anast. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 26–31, 81, illus. 3 references.

Requirements for aircraft stability; development of electronic equipment that provides for aircraft stability with easing the associated control problems; automatic pilots and their performance; results of tests carried out by the U.S.A.F. All Weather Flying Division on landing and approach control; design and evaluation of automatic control equipment.

Faster Reacting Autopilot for Speedy B-47. Philip Klass. *Aviation Week*, Vol. 56, No. 5, February 4, 1952, p. 42, 43, illus.

Design, operation, and performance of the Sperry A-12D autopilot for the Boeing B-47 jet bombers. The autopilot has a rapid response; it reduces the time needed for corrective changes in attitude of a flight path prior to a straight and level bomb run.

New Autopilot Going on Navy Jets. Philip Klass. *Aviation Week*, Vol. 56, No. 9, March 3, 1952, pp. 38, 41, 42, 44, illus. Design, development, and operation of the General Electric Navy Type G-3 autopilot for all-weather jet fighter aircraft.

Readers' Forum: Frequency Response of an Airplane from Flight-Test Data. G. M. Andrew and J. H. Polve. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, p. 285, illus. 2 references.

Notes on Dynamics for Aerodynamicists. J. D. Schetzer. *Douglas Aircraft Company, Inc., Report No. SM-14077*, November 19, 1951. 203 pp., illus. 39 references.

Fundamental ideas and mathematical techniques that form the basis of current methods for calculating the stability and response of an aircraft, based on the use of the Transfer Function Fourier concept. The theory is applied to obtaining the stability and control characteristics of an automatically controlled elastic aircraft. The behavior of the autopilot-aircraft system is analyzed in detail, emphasizing autopilot response and error factors.

What the (Sperry) Engine Analyzers Are Doing. *Sperryscope*, Vol. 12, No. 8, Winter, 1952, pp. 8–11, illus. Examples of the performance of the Sperry Engine Analyzer, and of the types of problems solved by the Analyzer.

Comparison of Airspeed Calibrations Evaluated by the Accelerometer and Radar Methods. Lindsay J. Lina and James P. Trant, Jr. *U.S., N.A.C.A., Technical Note No. 2570*, January, 1952. 16 pp., illus. 3 references.

The Measurement and Presentation of Rate of Fuel Flow. W. G. Askew. *Aeronautics*, Vol. 26, No. 1, February, 1952, pp. 71, 72, illus.

Requirements for fuel-consumption-rate meters; characteristics and operation of some available mass-flow, inferential, and volumetric meters; examples of American and British aircraft fuel meters.

Problems of Fluid Measurement. M. Schatzmann. (*Schweizerische Technische Zeitschrift*, No. 43, October 25, 1951, pp. 747–751.) *Engineers' Digest*, Vol. 13, No. 1, January, 1952, pp. 15, 16, illus. Characteristics and methods of operation of various types of flowmeters.

Fundamentals of Orifice Measurement. F. M. Partridge. *Instruments*, Vol. 25, No. 2, February, 1952, pp. 207–209, illus.

Continuous-Trace Recording System for Fight Testing an Orenda Gas Turbine. H. W. Wilson. **Appendix: Technique of Balancing Heiland Galvanometers.** Wendell S. Bacon. *Canada, National Aeronautical Establishment, Flight Research Section, Laboratory Report No. LR-13*, September 26, 1951. 69 pp., illus. 4 references.

Recording equipment and measuring methods of a system that simultaneously records the 74 measurements required to determine the performance of an Avro Orenda turbojet engine in an Avro C-100 aircraft in flight. The measurements are sensed almost entirely by standard gas turbine pick-up units and transformed into the deflection of light spots across continuously moving film. The appendix deals with the balancing jigs and procedures required for the Heiland galvanometers which were adapted to the recording-system.

Graphic Recorder Plots Level in Either Polar or Linear Coordinates. *General Radio Experimenter*, Vol. 26, No. 8, January, 1952, p. 7, illus.

Operation of the model PFR Polinear Recorder that automatically plots in pen and ink the a.c. or d.c. electrical voltage levels of pattern-emitting or -receiving devices, such as antennas or light sources, in either polar or rectangular coordinates on linear, square-root, or decibel scales.

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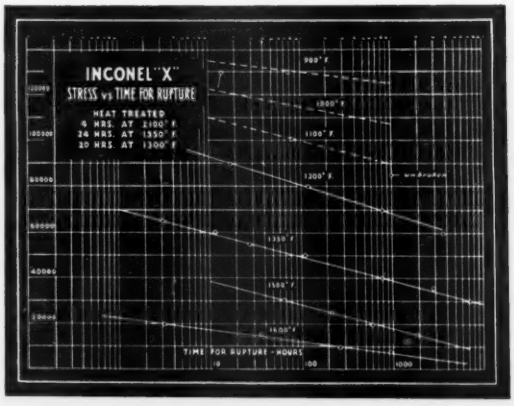

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Integrated Instrumentation for Modern Aircraft. Lynn S. Beals, Jr. *Aeronautical Engineering Review*, Vol. 11, No. 5, May, 1952, pp. 50–54. 2 references.

General philosophy of function instrument design which integrates the role of the human operator with instrument performance; cockpit instrument panels developed according to this philosophy at the Special Devices Center, Office of Naval Research.

A Generalized Method for Analyzing Servomechanisms. Arthur A. Hauser, Jr. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 197–202, illus. 3 references.

Presentation of a method for analyzing any type of carrier-frequency servomechanism. The technique employs the theory of linear spaces in the form of the algebra of dyadics through which the concept of transfer function is generalized to that of transfer-operator. For a symmetric side-band carrier-frequency servo or a d.c. servo, the operators reduce to the ordinary transfer functions of the system components.

A Theory of Multidimensional Servo Systems. Michael Golomb and Eugene Usdin. *Franklin Institute, Journal*, Vol. 253, No. 1, January, 1952, pp. 29–57, illus. 6 references.

Establishment of general performance criteria for an n-dimensional servo system that is a combination of n simple servomechanisms with coupled error-measuring devices; stability of such systems; root-mean-square error and integrated-square error criteria. Error-coefficient matrices provide a standard for the quality of reproduction of typical inputs.

Multiple Mode Operation of Servomechanisms. Donald McDonald. *Review of Scientific Instruments*, Vol. 23, No. 1, January, 1952, pp. 22–30, illus. 1 reference.

Analysis of the multiple modes of operation of conventionally designed servomechanism systems; design of a controller that makes use of the additional modes of operation and that produces a servomechanism having improved response with less weight than servomechanisms designed for only one mode of operation.

An Electronic Servo Simulator. N. T. van der Walt. *Electronic Engineering*, Vol. 24, No. 288, February, 1952, pp. 52–57, illus. 4 references.

A Homopolar Tachometer for Servomechanism Application. Craig C. Johnson. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 2, February, 1952, pp. 158–160, illus.

Design considerations, construction details, and performance for a small disc-type homopolar tachometer that serves as a low inertia, low noise, low friction rate signal source in a high-performance servomechanism.

Stroboscope Tachometer. Alvin B. Kaufman. *Machine Design*, Vol. 24, No. 2, February, 1952, pp. 157–160, illus.

Design and operation of two types of stroboscopic test units, one with variable flash frequency and one with fixed flash frequency, for accurately checking the calibration of generator-type tachometers for jet and reciprocating engines.

Laws & Regulations (44)

Airline Labor Policy, the Stepchild of the Railway Labor Act. James B. Frankel. *Journal of Air Law and Commerce*, Vol. 18, No. 4, Autumn, 1951, pp. 461–486. 41 references.

Legal Implications of Agricultural Aviation. Peter J. McBreen. *Journal of Air Law and Commerce*, Vol. 18, No. 4, Autumn, 1951, pp. 399–408. 24 references.

Legal Aspects of Air Transportability of the Sick. Gilbert L. Dunnahoo. *Journal of Aviation Medicine*, Vol. 23, No. 1, February, 1952, pp. 3–9, 18. 10 references.

Legal Aspects of Space Travel. Oscar Schachter. (*Hayden Planetarium Symposium on Space Travel*, New York, October 12, 1951.) *British Interplanetary Society, Journal*, Vol. 11, No. 1, January, 1952, pp. 14–16.

The Cabotage Concept in Aviation. I, II. *Interovia*, Vol. 7, Nos. 1, 2, January, February, 1952, pp. 41–44; 97, 98. 14 references.

Analysis of the history of sea and air cabotage and of the effects of cabotage on present-day air transport. Modifications are proposed to remedy the economic, sociological, and political disadvantages of cabotage.

Sovereign Immunity of Foreign Government-Owned Airlines. *Journal of Air Law and Commerce*, Vol. 18, No. 4, Autumn, 1951, pp. 455–460. 69 references.

Machine Elements (14)

An Electronic Flip-Flop As a Machine Element. John B. Flynn. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 124–129, illus. Use of an electronic counter as a measurement and/or control device. Block diagrams show arrangement of elements for counting, sorting, and weighing applications.

BEARINGS

American Standard Tolerances for Ball and Roller Bearings. II. *Tool Engineer*, Vol. 28, No. 2, February, 1952, pp. 69, 70, illus. Tables of ABEC-3 annular ball bearings and ABEC-5, RBEC-5 annular ball and cylindrical roller bearings, except magneto bearings; tolerances in 0.0001 in.

Nylon Parts for Ball Bearings. F. W. Recknagel. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 119–123, illus. Properties of molded nylon bearing parts; efficiency and endurance of nylon grease seals; molding, machining, and testing procedures.

Eleven Ways to Oil Lubricate Ball Bearings. D. L. Williams. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 166, 167, cutaway drawings.

The Stepped Shape Film Applied to a Journal Bearing. Frank R. Archibald. *Franklin Institute, Journal*, Vol. 253, No. 1, January, 1952, pp. 21–27, illus. 2 references.

Extension of Rayleigh's stepped-film design to the lubrication analysis of journal bearings. An explicit formula, in the form of a rapidly convergent series, is developed for the load supported by the stepped film for the case of a slider of finite width, including the effect of side leakage.

Oil Flow in Plain Journal Bearings. *U.S., National Bureau of Standards, Technical Report No. 1646*, March, 1952, 4 pp. 1 reference. A simplified method of analysis for the rate of oil flow in plain journal bearings.

FASTENINGS

Modern Aircraft Fittings. *Western Aviation*, Vol. 32, No. 2, February, 1952, p. 21, illus. Construction and applications of various types of aircraft "quick-disconnect" couplings.

MECHANISMS & LINKAGES

Mechanisms for Intermittent Motion. II, III. Otto Lichtwitz. *Machine Design*, Vol. 24, Nos. 1, 2, January, February, 1952, pp. 127–141; 146–155, illus.

Derivation of equations for and comparison of external and internal star-wheel mechanisms for obtaining intermittent motion from gears. Tables are given for the values of properties of the star-wheel mechanisms, and they are compared with the internal and external Geneva mechanisms.

SPRINGS

Design Charts for Large Compression Springs. *Product Engineering*, Vol. 23, No. 2, February, 1952, pp. 203, 205, 207, illus.

How to Choose Spring Materials. I. M. Gerard Fangemann. *Materials & Methods*, Vol. 35, No. 1, January, 1952, pp. 85–89, illus. Properties and applications of available spring types, and factors to be considered in selecting them. A table gives spring equations and definitions.

Maintenance (25)

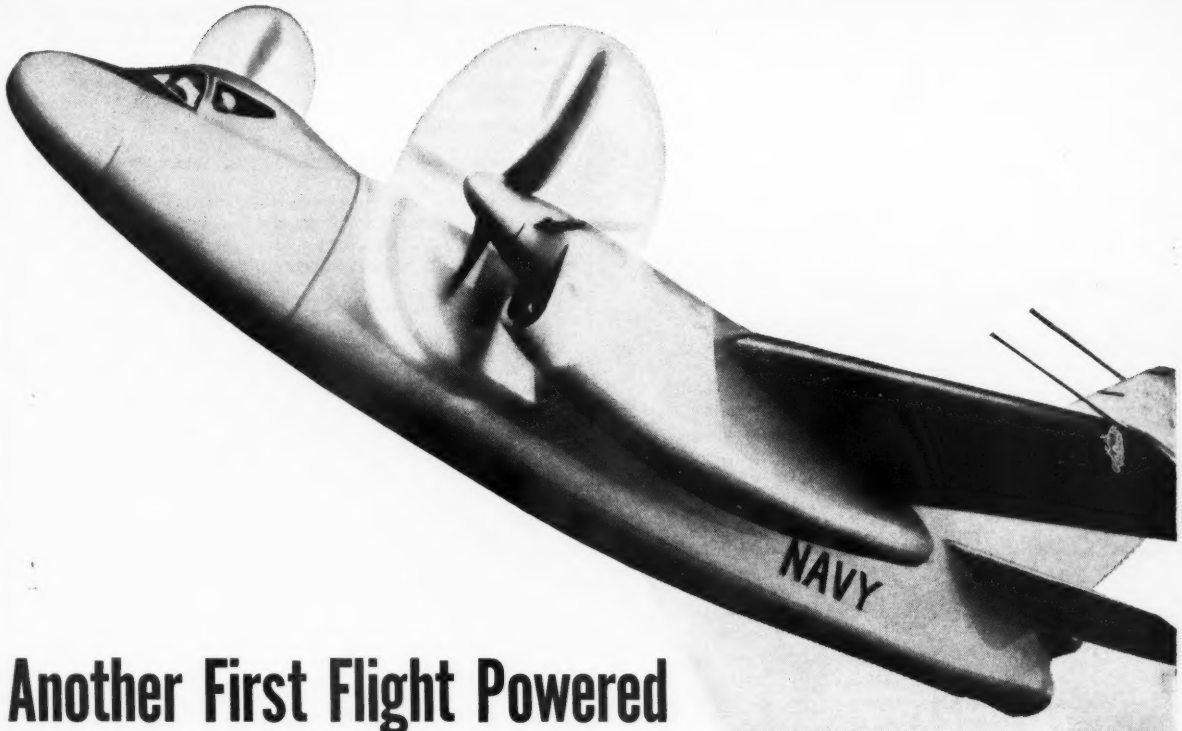
Douglas Service, Vol. 10, No. 1, January-February, 1952. 20 pp., illus. DC-4, DC-6A, -6B.

Noise Problems Associated with Aircraft Maintenance. Horace O. Parrack and Donald H. Eldredge. *Journal of Aviation Medicine*, Vol. 22, No. 6, December, 1951, pp. 470–576, illus. 4 references.

Materials (8)

Materials & Methods Manual No. 78: Review of Materials Engineering Developments in 1951. T. C. Du Mond. *Materials & Methods*, Vol. 35, No. 1, January, 1952, pp. 103–114, illus.

Major developments in irons and steels, nonferrous metals, nonmetallic materials, fabricated parts and forms, finishes and coatings, heat treating, cleaning and finishing, and welding and joining.



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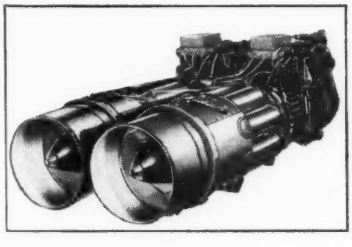

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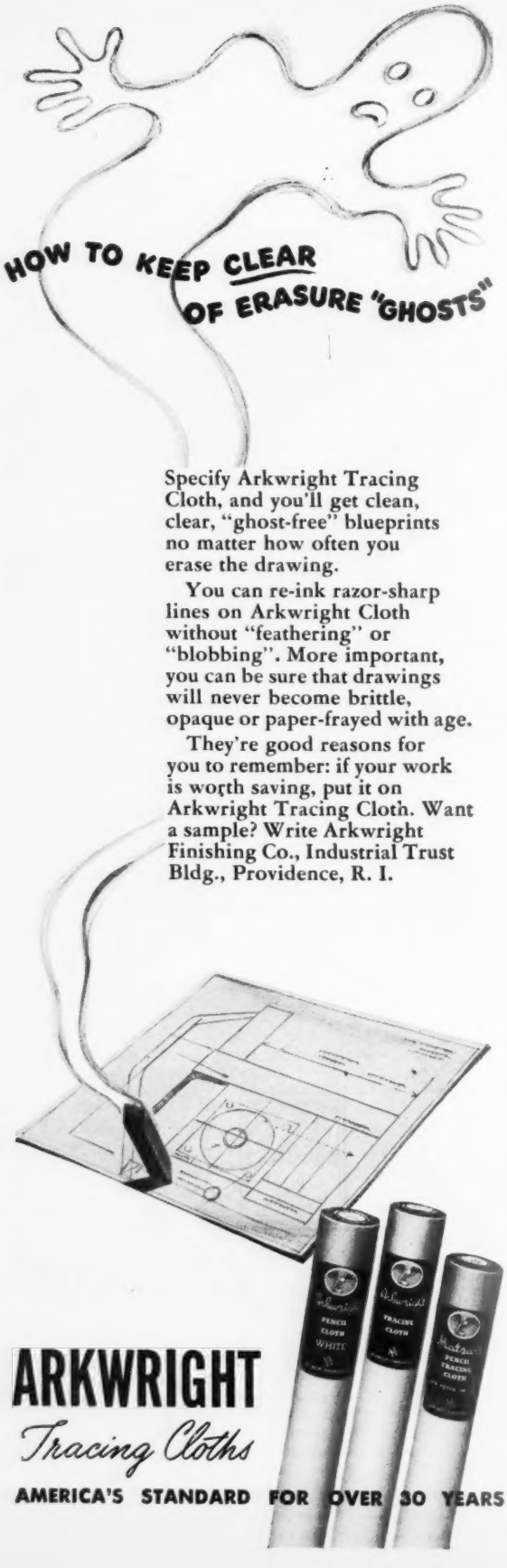
Builders of J35 Axial, J33 Centrifugal Flow Turbo-Jet Engines, T38 and T40 Turbo-Prop Engines

PROOF-TESTING ENGINES TODAY FOR THE AIRPLANES OF TOMORROW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The Notch Toughness Test of Henri Schnadt. Wendell P. Roop. *American Society for Testing Materials, Bulletin*, No. 179, January, 1952, pp. 61–64, illus. 10 references. An evaluation of the laboratory test method of notch toughness developed by Henri Schnadt and of the theory on which it is based; comparison with other tests.

CERAMICS & CERAMALS

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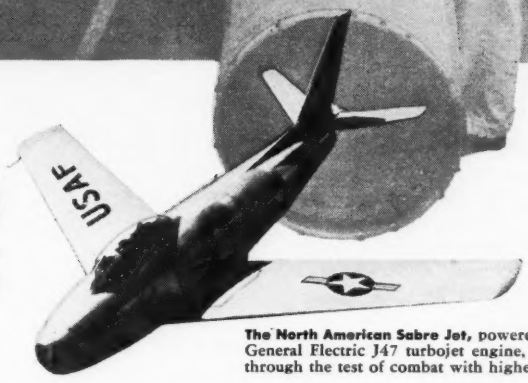

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Film Reader for Telemetered Information. *U.S., National Bureau of Standards, Technical Report No. 1623,* February, 1952. 7 pp., illus.

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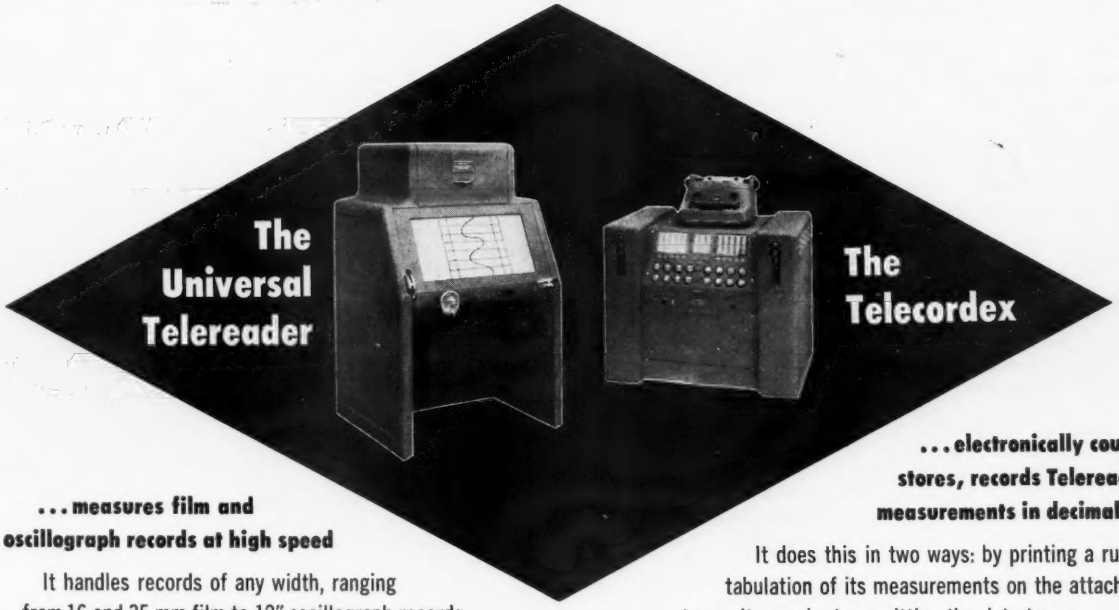

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An Investigation into the Effect of Forced and Natural Afterbody Ventilation on the Hydrodynamic Characteristics of a Small Flying Boat (Saro 37) with a 1:15 Fairing over the Main Step. J. A. Hamilton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2463*, 1951 (December 23, 1946). 28 pp., illus. 7 references. British Information Services, New York. $1.70.

Wind Tunnels & Research Facilities

Current Projects in Aerodynamics Laboratory, Aircraft and Allied Instrument Laboratory, Engine Laboratory, Engineering Section, Flight Research Section, Fuels and Lubricants Laboratory, Gas Dynamics Section, Low-Temperature Laboratory, Structures Laboratory. *Canada, National Research Council, Aeronautical Laboratories, Quarterly, Bulletin, Report No. NAE 1951 (4)*, October 1–December 31, 1951, pp. 6–25, illus.

Electric Power for Jet-Engine Research. K. D. Brumbaugh. *Electrical Engineering*, Vol. 71, No. 2, February, 1952, pp. 118–123, illus. 3 references. Power distribution system of the N.A.C.A. Lewis Flight Propulsion Laboratory.

Tests on Yawed Aerofoils in the (N.P.L.) 20- by 8-In. High-Speed Tunnel. J. A. Beavan and N. Bumstead. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2458*, 1951 (July 10, 1947). 9 pp., illus. 2 references. British Information Services, New York. $0.65.

Analysis of results of tests on NACA 0020 sections that completely spanned the tunnel at yaw angles of 0° and 40° to determine the influence of wind-tunnel interference on the compressibility drag rise.

Shock-Tube Studies of Transonic Flow over Wedge Profiles. Wayland Griffith. *Journal of the Aeronautical Sciences*, Vol. 19, No. 4, April, 1952, pp. 249–257, 264 illus. 23 references.

A method by which a shock tube is used as an intermittent wind tunnel in which flow patterns in the transonic range are determined using a Mach-Zehnder interferometer. Steady flow fields around two-dimensional wedges were studied over a Mach Number range of 0.85 to 1.80.

Spectrum of Turbulence in a Contracting Stream. H. S. Ribner and M. Tucker. *U.S., N.A.C.A., Technical Note No. 2066*, January, 1952. 54 pp., illus. 12 references.

Analysis, using the spectrum concept, of the selective effect of a stream contraction on the lateral and longitudinal turbulent velocity fluctuation of the stream, assuming negligible decay. Inclusion of the decay term in the first approximation leads to a theory that may be useful in wind-tunnel-design applications.

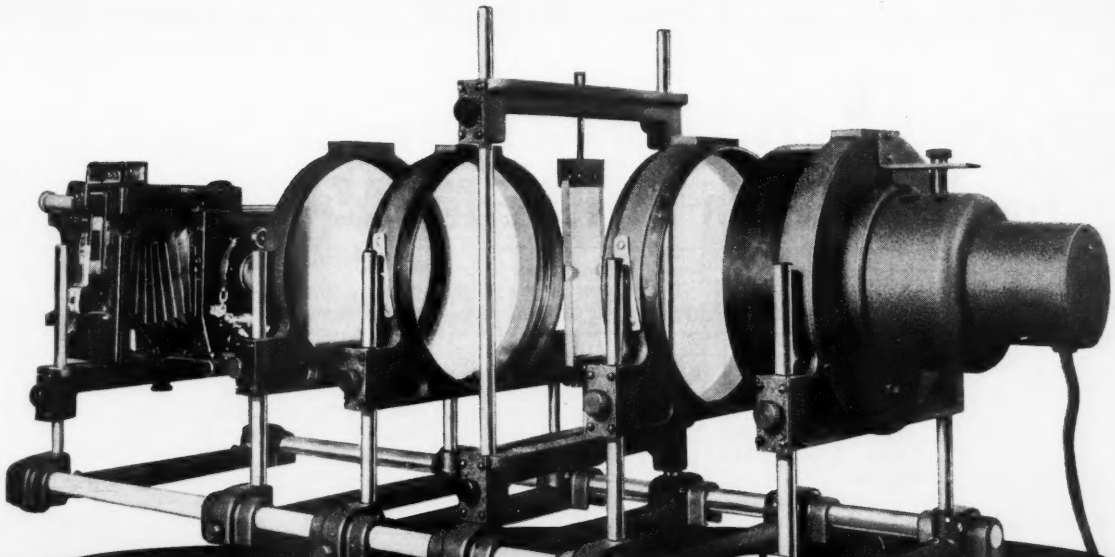
France's Latest Wind-Tunnel. Georges Bruner. *The Aeroplane*, Vol. 82, Nos. 2116, 2118, February 8, 22, 1952, pp. 161–164; 216–219, illus.

Development, layout, design details, and aerodynamic circuit of the 100,000-hp. hydraulically driven wind tunnel at Mondane which has an expected Mach Number range of $M = 0.2$–1.15. Data are also given on the design and operation of the balance and measurement apparatus, on the aerodynamic effectiveness of the tunnel, and on the efficiency of the hydraulic plant.

Ein neues, sehr einfaches Interferometer zum Erhalt quantitativ auswertbarer Stromungsbilder. S. F. Erdmann. *Applied Scientific Research, Section B, Electrophysics, Acoustics, Optics, Mathematical Methods*, Vol. B2, No. 3, 1951, pp. 149–198, illus. 7 references. In German.

Design and principles of operation of a new simple interferometer for the quantitative measurement of subsonic and supersonic flow patterns; performance; test results. The interferometer is designed on phase-contrast methods based on the theory of Zernike.

Calculated Pressures Ahead of Struts and Wings. E. R. Crabbe and K. V. Diproso. *Gt. Brit., Royal Aircraft Establishment, Technical Note No. Aero. 1516*, October, 1944. 6 pp., illus. 1 reference. Curves are presented for the calculated pressures ahead of three shapes of strut sections: the ellipse, the Hartshorn strut form, and the simple Joukowski airfoil.



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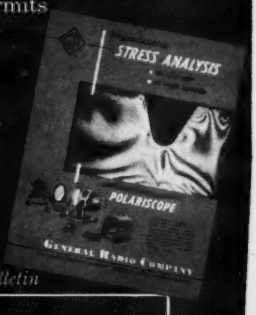

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Aeronautical Reviews — BOOKS

Book Notes

ELECTRONICS

The Theory of Electromagnetic Waves; A Symposium Held Under the Auspices of The Washington Square College of Arts and Science and the Institute for Mathematics and Mechanics of New York University and the Geophysical Research Directorate of the U.S.A.F. Cambridge Research Laboratories, June 6–8, 1950. New York, Interscience Publishers, Inc., 1951. 393 pp. illus., diagrs., figs. $6.50.

The proceedings of this Symposium have been published simultaneously in *Communications on Pure and Applied Mathematics*, Vol. 3, 1950, No. 4, pp. 355–449; Vol. 4, 1951, No. 1, pp. 33–160, and No. 2-3, pp. 225–378.

Contents: On the Theory of Electromagnetic Wave Diffraction by an Aperture in an Infinite Plane Conducting Screen, H. Levine and J. Schwinger. On Systems of Linear Equations in the Theory of Guided Waves, W. Magnus and F. Oberhettinger. Wiener-Hopf Techniques and Mixed Boundary Value Problems, S. N. Karp. Asymptotic Solutions of a Differential Equation in the Theory of Microwave Propagation, R. E. Langer. Criteria for Discrete Spectra, K. O. Friedrichs. Extension of Weyl's Integral for Harmonic Spherical Waves to Arbitrary Wave Shapes, H. Poritsky. Kirchhoff's Formula, Its Vector Analogue, and Other Field Equivalence Theorems, S. A. Schelkunoff. On the Diffraction Theory of Gaussian Optics, H. Bremmer. Diffraction and Reflection of Pulses by Wedges and Corners, J. B. Keller and A. Blank. Vector Wave Functions, R. D. Spence and C. P. Wells. The W. K. B. Approximation As the First Term of a Geometric-Optical Series, H. Bremmer. Remarks Concerning Wave Propagation in Stratified Media, S. A. Schelkunoff. The Theory of Magneto Ionic Triple Splitting, O. E. H. Rydbeck. An Asymptotic Solution of Maxwell's Equations, M. Kline. Field Representations in Spherically Stratified Regions, N. Marcuvitz. Propagation in a Non-Homogeneous Atmosphere, B. Friedman. Reflection of Electromagnetic Waves from Slightly Rough Surfaces, S. O. Rice. The Theory of Scattering of Radio Waves in the Troposphere and Ionosphere (Abstract), H. G. Booker. Properties of Guided Waves on Inhomogeneous Cylinidrical Structures (Abstract), R. B. Adler. Evaluation of Integrals Associated with Wave Motion in Dispersive Media and the Formation of Transients (Abstract), M. Cerrillo. Electromagnetic Research in the U.S. Air Force Research Program. N. C. Gerson.

MATERIALS

METALS & ALLOYS

Standard Methods of Analysis of Iron, Steel and Ferro-Alloys As Used by the Laboratories of The United Steel Companies Limited. 4th Ed. Sheffield, England, The United Steel Companies Ltd., 1951. 169 pp., figs., $3.50.

The major addition to this edition is a new section dealing with physico-chemical methods that have proved of value in service. All the methods, which are principally chemical, have been fully reconsidered, and some have been revised. Several have been replaced, and methods for boron and iron have been included. Excluded are some rapid methods employed in the plant for control purposes.

Contents: Part 1, Analysis of Irons and Steels—Aluminum, Arsenic, Boron, Carbon, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Molybdenum, Nickel, Niobium (Columbium) Plus Tantalum, Nitrogen, Phosphorus, Selenium, Silicon, Sulphur, Tin, Titanium, Tungsten, Vanadium, and Zirconium Methods. Part 2, Special Analytical Methods—Absorptiometric Methods (Chromium, Cobalt, Manganese, Molybdenum, Nickel, Nitrogen, Silicon, Titanium, and Tungsten), Polarographic Methods (Copper and Lead), and Mercury Cathode Separations. Part 3, Analysis of Ferro Alloys—Ferro-Manganese and Spiegel Alloys, Silico-Manganese, Ferro-Silicon, Ferro-Chromium, Ferro-Molybdenum, Ferro-Titanium, Ferro-Tungsten and Tungsten Powder, Ferro-Vanadium. Part 4, Fluorspar. Table of Atomic Weights.

Proceedings at a Symposium on Welding and Riveting Larger Aluminium Structures, London, November, 1951. London, The Aluminium Development Association, February, 1952. 223 pp., figs.

Included are reports of discussions, authors' replies, and full texts of the following papers: Recent Researches on the Arc Welding of Thick Aluminium Alloy Plate, P. T. Houldcroft, W. G. Hull, and H. G. Taylor. Practical Aspects of the Argon-Arc Welding of Aluminium Alloys, J. R. Handforth. The Properties and Driving of Large Aluminium Alloy Rivets, J. C. Bailey. The Design Characteristics of Aluminium Riveted Joints, S. C. Redshaw.

NAVIGATION

Principles of Air Navigation. E. W. Anderson. London, Methuen & Company, Ltd., 1951. 264 pp., diagrs. 25*s*.

New equipment and methods developed since the war form the basis for this treatise on modern air navigation. The approach of the author to his subject is practical and reflects his wide experience as a navigator with the R.A.F. and with British and American air-line companies. Much of the material and many of the illustrations were first published in issues of *The Aeroplane* under the by-line of "Navigus." Part 1, Physics, contains two chapters, the first on mathematics and mathematical devices and the second on the earth's rotation, distances, directions, routes, and magnetism. Part 2, Equipment, is concerned with the details of maps and charts; compasses; and various flight, chronometric, and plotting instruments. In the next section—on flight planning—winds, fronts, pressure-pattern flying, and complete preflight preparation are covered. Part 4 deals with the general principles of position finding, visual aids, radio equipment and its use, radar devices, hyperbolic systems, and astronavigation procedures and aids. In the last part, dead reckoning and technique are discussed. Under the chapter heading of Technique are treated long-range navigation (transoceanic, polar, and tropical), short-range navigation (including air-traffic control and blind approach and landing), tactical navigation (search, interception, and radius of action), and special techniques (high-speed navigation, navigation in formation, and navigation in war). The detail of the subject index and table of contents makes the volume useful also as a book of reference.

For information on I.A.S. Library Service Facilities, see page 99

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

REFERENCE WORKS

The Aeroplane Directory of British Aviation, Incorporating Who's Who in British Aviation. Compiled by the Staff of *The Aeroplane*. 1952 Ed. London, Temple Press, 1952. 434 pp. 15*s*.

The principal changes in this year's volume on British and Commonwealth aviation are a regrouping of the information for easier reference and an enlargement of the alphabetical index to cover all of the directory sections more comprehensively. These directory sections present data on service and commercial aviation; civil ministries, establishments and boards; the aircraft industry; international civil organizations; learned bodies, professional societies, and clubs; the aeronautical press; and aeronautical training.

SCIENCES, GENERAL

MATHEMATICS

Tables of the Exponential Function e^x. 3rd Ed. (U.S., National Bureau of Standards, Applied Mathematics Series, Vol. 14.) Washington, U.S. Govt. Printing Office, 1951. 537 pp. $3.25.

No major changes have been introduced in this edition. One error in a functional value and several misprints in the arguments have been corrected, and the values of e and of $1/e$ to 2,556 decimal places have been included.

Table of Circumferences and Areas. U.S., National Bureau of Standards, Mathematical Tables Project. (U.S., Navy, Bureau of Ordnance, Publication No. OD 5797.) Washington, Superintendent of Documents, March 21, 1947. 101 pp. $0.45.

The computations are based on the value of π to eight significant figures, with a partial adjustment for the rounding error in π. The tabulated values of the circumference and area are in error by, at most, one unit in the last place.

SPACE TRAVEL

The Artificial Satellite; Proceedings of the 2nd International Congress on Aeronautics, London, 1951. Edited by L. J. Carter. London, British Interplanetary Society, 1952. 74 pp., illus., diagrs., figs. 5*s*. 6*d*. $0.75.

This volume contains a full report of the Proceedings of the Congress, the complete papers presented by the B.I.S. (British Interplanetary Society), summaries of papers presented by other societies, and a list of societies in various countries which are interested in space flight. The B.I.S. papers published in full are: The Artificial Satellite, L. R. Shepherd; Interplanetary Travel Between Satellite Orbits, L. Spitzer; Descent from Satellite Orbits Using Aerodynamic Braking, T. Nonweiler; Meteor Hazards to Space-Stations, M. W. Ovenden; Minimum Satellite Vehicles, K. W. Gatland, A. M. Kunesch, and A. E. Dixon; and Establishing Contact Between Orbiting Vehicles, R. A. Smith. The papers summarized are: The Importance of Satellite Vehicles in Interplanetary Flight, Wernher von Braun; Landing of Space-Craft, E. G. Ewing; Biological Problems of the Earth Satellite Vehicle, P. Bergeret; The Optimum Satellite Freight Rocket, H. Hoeppner; Start, Return and Landing of an Optimum Satellite Step Rocket, H. Kuhme; The Foundation of the Space-Station, G. von Pirquet; Optimum Orbit of a Space-Station for Radar Tracking, R. Merten; Design Problems of the Space-Station, H. H. Koelle; Proposal for the Construction of a Space-Station, A. Püllenberg; The Space-Station as an Astronomical Observatory Site, A. L. Joquel, II; and How Will the Space-Station Be Constructed? R. Nebel.

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THERMODYNAMICS

Engineering Thermodynamics. Newton C. Ebaugh. 2nd Ed. New York, D. Van Nostrand Company, Inc., 1952. 398 pp., figs. $5.75.

The aim of this second edition is to present the essentials of thermodynamics as they apply to modern industrial equipment. Changes necessitated by new advances in recent years have been made in the text, in the problems, in the illustrations, and in the charts. Prerequisites for use of the book are general physics, inorganic chemistry, and mathematics through calculus. The first eight chapters explain the fundamental data and are recommended for inclusion in all courses. The later chapters may be used as the nature of the course requires. Literature references are listed at the ends of chapters.

Contents: Chapter 1, Thermodynamics and Energy. Chapter 2, State and Changes of State. Chapter 3, Energy Equations. Chapter 4, Gas Properties and Processes. Chapter 5, Cycles and Available Energy. Chapter 6, Entropy. Chapter 7, Vapor Properties and Processes. Chapter 8, Gas Mixtures; Gas and Vapor Mixtures. Chapter 9, Flow of Fluids. Chapter 10, Vapor Power Cycles. Chapter 11, Steam Engines. Chapter 12, Steam and Gas Turbines. Chapter 13, Gas Power Cycles. Chapter 14, Gas Compression. Chapter 15, Refrigeration Cycles. Chapter 16, Generation of Heat. Chapter 17, Flow of Heat. Answers to Exercises.

Table 1—Saturation: Temperatures. Table 2—Saturation: Pressures. Table 3—Superheated Vapor. Index.

Appendix 1—Mollier Chart for Steam. Appendix 2—Mollier Chart for Ammonia. Appendix 3—Temperature-Entropy Diagram for Air. Appendix 4—Mollier Chart for Air. Appendix 5—Temperature-Entropy Diagram for Carbon Dioxide. Appendix 6—Pressure-Enthalpy Diagram for Freon-12. Appendix 7—Psychometric Chart.

VIBRATION

Mechanics of Vibration. H. M. Hansen and Paul F. Chenea. New York, John Wiley & Sons, Inc., 1952. 417 pp., figs. $8.00.

This book has arisen out of a course in vibration analysis which has been offered for several years by the Department of Engineering Mechanics of the University of Michigan, where the authors are, respectively, Professor and Associate Professor of Engineering Mechanics. The aim of the book is to present the fundamentals and basic theory in a manner readily understood by the undergraduate who has had an elementary course in dynamics and the standard undergraduate instruction in mathematics, and, at the same time, to be sufficiently thorough for the graduate student. The first part of the text deals at some length with steady-state vibrations of systems of one degree of freedom. The second part extends the theory to systems of several degrees of freedom. The theory is discussed from the classical standpoint, although emphasis has been placed on the "mobility" concept. The third and final part is an introduction to special topics that are an essential part in a more general and more refined analysis of vibration problems. These special topics include nonlinear systems, systems with distributed physical characteristics, and systems subjected to transient motions. A subject index has been provided, and there is an 88-page section of problems for solution by the student. Answers are also included.

Pointed out by the authors as important features of the book are: the use of the concept of relaxation frequency and its physical meaning throughout; the stressing of the use of equivalent springs, dampers, and masses, as well as dimensionless parameters; the use of energy methods and Rayleigh's method; the extensive treatment of the mobility method; and the considerable attention given to the solution of the frequency equation.

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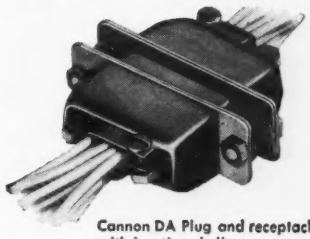

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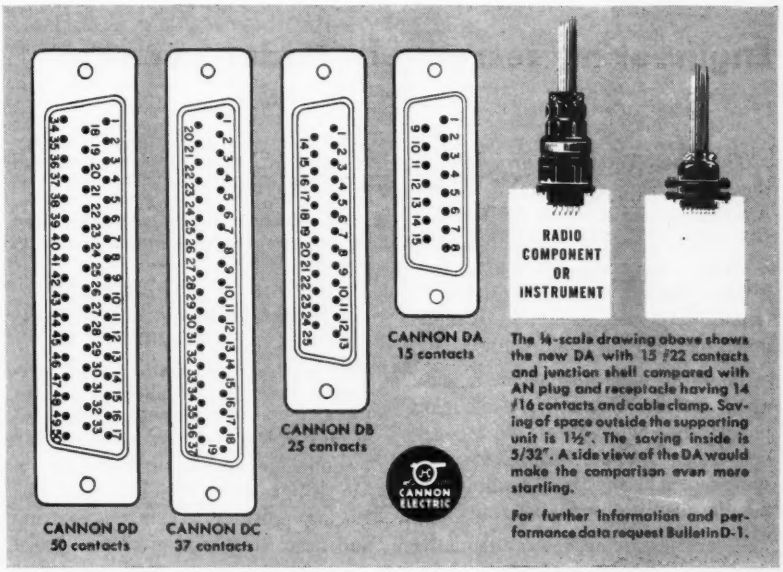

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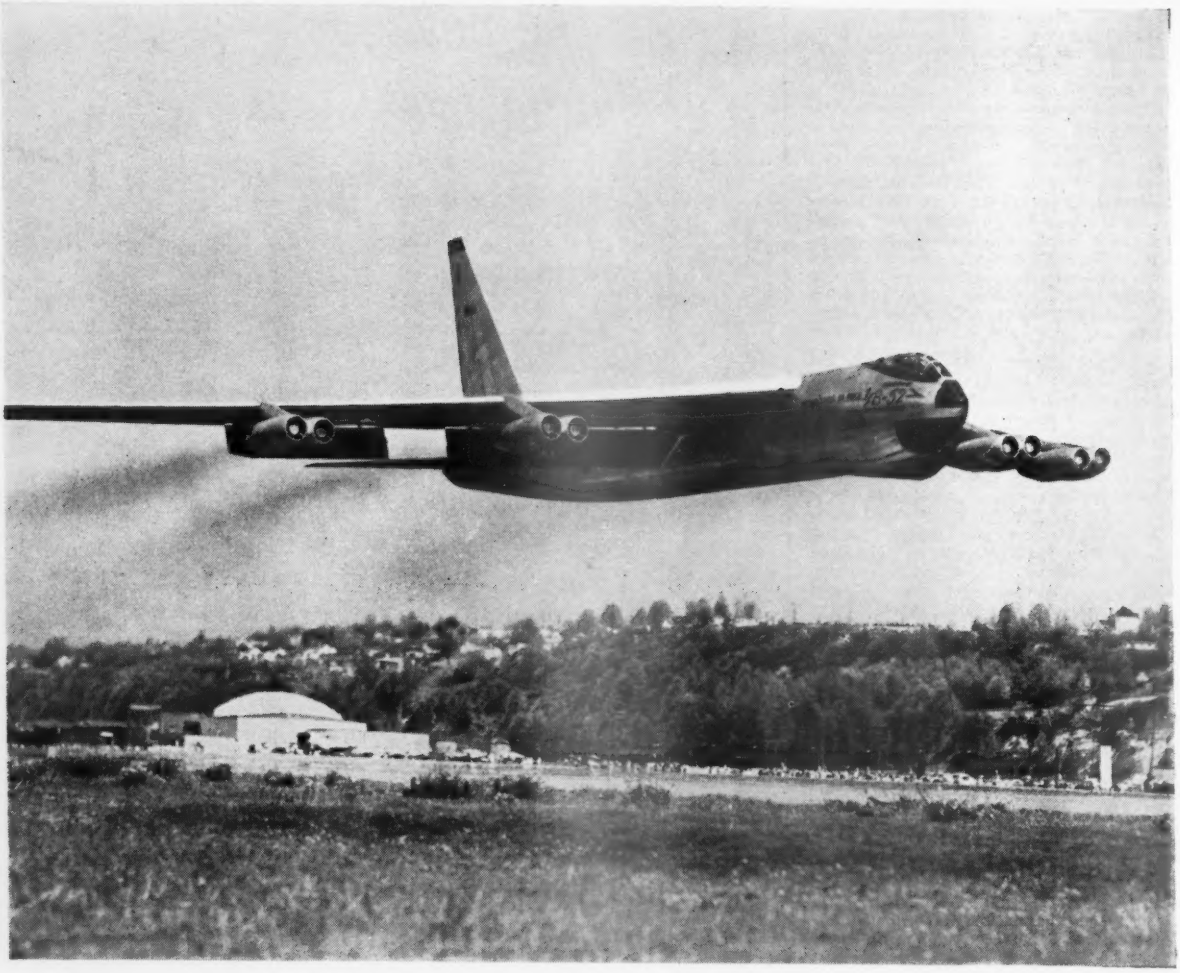

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392. Aeronautical Engineer—B.S. in Ae.E. Well-rounded background of 15 years of military aircraft design, supervisory and administrative experience, including 5 years of guided missiles experience. Seeking new connection in design supervisory, executive, or administrative capacity in aircraft, missiles, or any allied field. Past experience includes positions as Project Engineer, Assistant Project Engineer, Chief Draftsman, Chief Standards Engineer, Power-Plant Group Leader, Armament Group Leader, and many others.

389. Aeronautical Engineer—M.S. in Ae.E. Nine years' experience in aircraft. At present employed as head of aero elasticity section.

388. Structural Engineer—Twenty-five years' structural stress and design analysis, all types of framed structures, including chief of structures of helicopter company and aircraft job shop. Registered structural engineer, various states. Desires to locate in Arizona or Nevada.

387. Aeronautical Engineer—With 15 years' practical experience; Scottish-born Canadian citizen residing in Canada; 3 years' flight testing instruments and accessories; 4 years' manufacture of aircraft hydraulics and controls; 3 years' design of special ground apparatus for R.C.A.F.; 5 years' research, design, development, and testing of reciprocating and turboprop engines. Also 16 years' practical electromechanical engineering experience prior to entering aviation field. Seeks aeronautical engineering and/or sales liaison job anywhere within British Empire and Commonwealth.

386. Design Engineer B.Ae.E., M.I.A.S.; age 34. Twelve years' design experience in aircraft mechanisms and hydraulics. Specialist in landing gear, controls, hydraulic circuits and components, and armament. Lead layout man and group engineer with major aircraft companies; project engineer with aircraft component suppliers and test equipment manufacturers; overseas specialist for foreign government. Thoroughly experienced in analysis and design of oleo shock struts, hydraulic servomechanisms, boost controls, and power controls. Prefers job with large design responsibility rather than heavy administrative responsibility. Will locate anywhere overseas or on either coast of United States.

385. Professor—Academic position with rank of Associate or Assistant Professor desired for the 1952–1953 year. Excellent qualifications with regard to academic training in engineering and mathematics, industrial experience, and published works. Specialist in flutter and vibration, rotary wing aircraft, automatic controls, and analog and digital computation. Complete details on request.

384. Mechanical Engineer—California Register. Thirteen years' experience; 2 years' teaching evening classes, Washington University, St. Louis, Mo. Supervisory experience includes 3 years Chief of Design, 1 year Project Engineer (power plant), 1 year Group Engineer (power plant), 1 year lead man (power plant and preliminary design), 2½ years as specialist in charge of prototype design on a Mach 2.75 missile. Active vendor and special warhead contacts 1946 to present. Active Wright Field and BuAer contacts 1943–1945; active C.A.A. Washington contacts 1945, 1946. Two and one-half years' flight and bench test work. Experienced in preliminary design (8 years), including practical estimations of man power (shop and engineering) and material costs. Experienced in writing

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383. Flutter and Vibration Engineer—Bachelor and Master's degree in Aeronautical Engineering. Aggregate of 5 years of experience in dynamics field. One year at N.A.C.A. as a structural research scientist; 1 year at a leading jet aircraft manufacturer as a flutter engineer, and 3 years at a leading helicopter manufacturer as assistant chief of vibrations department, which includes design experience in vibration isolation equipment. Desires position in the New York City area.

382. Engineer—M.S. Nine years' experience in system dynamics and servomechanisms. Presently head of servo group of large aircraft company. Desires position with increased scope; New York area.

381. Project Manager and Engineer—More than 11 years' intensive experience as a project engineer and development engineer. Aptitude for organizing, planning, and executing engineering and manufacturing operations. Experience in aircraft and nonflying gas turbines, aircraft superchargers, centrifugal compressors, natural gas pipe-line boosters, and flight-testing military aircraft. Much practice in dealing with customers and subcontractors.

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